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ABSTRACT

This handbook for Peace Corps agricultural programmers, trainers, and volunteers is designed to aid them in identifying storage problems and devising solutions to them. Part 1 covers grain storage project programming. Information provided for the volunteers involved in grain storage projects includes project goals and objectives as well as methods to assess local government interest and to investigate local storate conditions. Development of a strategy for volunteer involvement in postharvest project activities is discussed. The determination of program support needs and integration of storage project activities with rural development efforts are also considered. Local and international programming and training resources are suggested. Part 2 includes 11 training subject areas for use in storage program training sessions or in volunteer self-instruction. They are: grain and grain storage in the world food supply, movement of grain from harvest to consumer, physical properties of grain, moisture and its measurement, factors that threaten good preservation of grain, grain drying, insects and control, rodents and control, recognition of storage problems, design and field testing of improved storage technologies, and extension of improved storage technologies. For each area this information is provided: major subject areas, training objectives, suggested resources, suggested training exercises, and informative material. A project report is appended. (YLB)

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Peace Corps

PROGRAMMING AND TRAINING FOR SMALL FARM GRAIN STORAGE

by

Carl J. Lindblad

September 1978

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Objectives of This Handbook

Traditional farming methods are based on centuries of experience and trial and error. Traditional farmers generally make effective, if not ingenious, use of the resources available to them in storing their grain. There are widely varied methods of grain storage at the subsistence and traditional farm level. Some methods are more successful than others, with relatively high losses in some areas and relatively low losses in others.

This Handbook is designed to aid Volunteers in identifying storage problems and devising solutions to them. Often, the improvement of traditional storage methods will entail the introduction of new or non-local materials, along with new methods and concepts for their use. This introduction of new resources, concepts and behaviors requires not only technical competence, but also cultural awareness and sensitivity to the needs, attitudes and priorities of the farmer.

The approach of this Handbook to technological innovation is based on the concept of Appropriate Technology, favoring technologies based on the local needs and resources of the farmer. This approach will generally be based on innovations which are inexpensive and labor intensive and which favor an improvement rather than replacement of the technology presently in use. Thus, the introduction of non-local or imported materials should be kept at a minimum. There will be circumstances in which significant departures from traditional storage methods will offer the best practical avenue for improvement of storage conditions. However, this can only be determined after other, less complex, radical, or costly alternatives have been found impractical. The emphasis for all innovations should be on simplicity, practicality, and local resources.

This Handbook is designed for use by Peace Corps agricultural programmers, trainers, and Volunteers. It provides guidance and technical resources for:

- Identifying farm-level storage projects as primary and secondary Volunteer activities.
- Defining project goals and objectives.
- Defining the Volunteer Job.
- Defining needs for pre- and in-service training and Volunteer self-instruction.
- Planning and conducting training sessions.

- Locating technical resource organizations to aid in the support of storage project planning, programming and training, and ongoing activities.

Because there are significant variations from country to country and even within countries in agricultural, economic, political, climatic, and cultural factors as well as in the level of Volunteer skills, general guidelines and information in this Handbook will require local adaptation.

Because there is considerable overlap in the technical materials required for programming and training of grain storage projects, there are references in sections of the Handbook to other sections as well as references to the Peace Corps/VITA *Small Farm Grain Storage Manual* and other supplementary technical resources. The technical materials presented in this Handbook, when used in conjunction with the aforementioned manual and *Handling and Storage of Food Grains in Tropical and Subtropical Areas* are sufficiently complete for the needs of Peace Corps programming and training. The use of local expertise will certainly improve quality of technical information and expertise to support Volunteer training and activities.

This Handbook is specifically designed for use in programming and training generalist Volunteers. Generalist Volunteers have effectively worked in the area of small farm grain storage in several countries and have been instrumental both in developing and popularizing improved storage methods at the farm level and in building local government interest and commitment to this area of agricultural development. That is not to say that generalists are the only Volunteers recommended for grain storage projects. But they are certainly capable of working in this area if they are programmed into projects for which they have been trained in appropriate skills and in which they are provided with technical supervision. The quality and competence of generalist Volunteer development activities depends directly on the quality and competence of the training and technical support.

Knowledge of and the use of all available technical resources are critical to the success of Volunteer activities, particularly in the case of generalist Volunteers. Potential sources of technical expertise and information available through worldwide organizations are listed in Section G, Local and International Programming and Training Resources. These are valuable resources of which Volunteers, trainers, and programmers are strongly encouraged to take full advantage.

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APPENDIX A

Peace Corps Costa Rica Grain Storage Project Report

PART I Grain Storage Project Programming

A. Grain Storage Project Goals and Objectives

Grain storage program conception and objectives will vary from country to country and within each country according to such criteria as the storage needs and problems encountered, the type of local technical support available, whether the project is a part- or full-time Volunteer activity, and so forth. However, there are basic objectives which will be present in every grain storage program.

Essentially Volunteers will promote storage methods which:

- Preserve the quantity of the harvest.
- Maintain its quality (food value).
- Result in the highest possible sale value for whatever grain is sold or traded.

Each of these objectives is compatible with the others, requiring the same kind of precautions on the part of the farmer. The farmer's ability and desire to pursue the three objectives will depend on a variety of factors including cultural influences, labor and cash resources available to allocate to storage, the climatic hospitality of the storage environment, and access to local resources such as insecticides, market transport, market price information, and the like.

The single most common activity of Volunteers in any type of storage project will be in the application and instruction of basic storage principles. Every training effort should include the following basic subject areas:

- Maintenance of storage hygiene.
- Control of grain moisture.
- Specific control of grain pests, i.e., insects, rodents and birds.

Volunteers involved in grain storage projects may work with individual farmers or farm cooperatives, family members responsible for storing grain, rural school students, extension agents, etc. The same basic storage principles and storage objectives will be common to whatever level of involvement Volunteers may pursue.

B. Assessing Local Interest in Postharvest Methods Improvement

Volunteer involvement in postharvest grain storage projects will often depend on the level of government interest and commitment to this area of development. It has not often been recognized that postharvest problems are within the realm of the agricultural extension service or that reducing postharvest losses is a potential solution to the problem of increasing the food supply. In countries where postharvest concerns are not a high priority, the first task may be to alert government officials to their importance. Lack of interest should not necessarily be assumed to be an accurate indicator of the local importance of grain storage problems.

Some initial areas of investigation to determine government interest include:

(1) Is there a government organization or office specifically devoted to postharvest research or extension? This role has recently been undertaken by plant protection offices in many agricultural ministries whose principal interests are with preharvest concerns such as in-field plant diseases and in-field bird, rodent, and insect infestations.

(2) Has the government made any efforts in postharvest grain loss reduction through educational programs for insecticide use, storage loss assessment, or improved drying or storage design research?

(3) What is the comparative importance of local development efforts in postharvest versus production areas? (e.g., in terms of budget, training, personnel, research, etc.)

(4) What training do extension agents receive in grain storage principles, improved drying and storage methods, and insecticide use?

(5) Do civil servants in agricultural extension or research believe that improved grain storage would increase the food supply? Do they feel that storage losses are significant? What do they think can or should be done about the problems?

(6) Is there an annual grain market price fluctuation, notably with high market prices occurring just before each new harvest? How does this affect farmer's storage practices?

(7) Do farmers think that they lose a lot of grain during storage, drying, or transport? Have they tried different ways to reduce the losses? Do they know of ways to reduce the losses?

C. Investigating Local Storage Conditions

The programming of Peace Corps Volunteers into primary or secondary grain storage activities will require some prior investigation into the nature of local storage practices and problems. This activity can rely in part on the experiences and opinions of rural development Volunteers already in the field. However, some time needs to be spent in field investigations in order to gain an understanding of the specific problems Volunteers might address and the activities in which they could be involved.

Full-time (as opposed to part-time) storage programs will require much more investigation and might justify a special programming mission. Appendix A is a report of a recent programming mission for Peace Corps/Costa Rica. This may serve as a model for program development where there is not similar local expertise available for program investigation and planning.

In circumstances where Volunteers are to be trained in a variety of rural development areas, much of the actual program development will be done by the individual Volunteers once they arrive on site. The following list of questions will be helpful in orienting the programmer, trainer, and Volunteer in identifying what potential there is for change or improvement of local postharvest practices. This list is not all-inclusive but could easily be adapted to a wide variety of climatic, cultural, and agricultural conditions.

LOCAL POSTHARVEST CONDITIONS SURVEY

(1) What are the methods of storage for the grains grown in your area: are they stored on the head or cob, threshed, or partially threshed; in mud or thatch bins, sacks, or clay jars; near the home, or in the field; in permanent stores or ones rebuilt each year?

(2) Are there different qualities of grain recognized by the farmers? Are they stored separately? Is the lowest quality consumed first or sold first, etc.?

(3) What are the drying practices? How is the harvest date determined? How do farmers know if their grain is dry enough to store? Are heads separated from the stalk at harvest, or dried on the stalk? Are they dried in the field or around the home? Are any measures taken during drying to protect against rodents? Birds? Insects? Do farmers think there are important losses which occur between harvest and storage? If there are differences in local drying practices, how does a farmer choose one method as opposed to another?

(4) Are there differences between present drying and storage practices and older, traditional methods? What are they? Why do farmers think the changes have come about?

(5) What losses, if any, are seen by the farmers and extension agents as being important, e.g., rodents, birds, insects, spillage or transport losses? If possible, rank as to importance for farmer, extension agent. What is your evaluation?

(6) What role do women have in harvesting, drying, and storing grain? Are there tasks performed by women which men are not permitted to do, or vice versa? Do the women think there is a problem of grain loss and why? When, if at all, does the grain become the partial or sole responsibility of the women?

(7) What kind of protective measures do farmers use against drying and storage losses, such as mixing sand or local plants with stored grain, smoking it above the cooking fire, re-drying, etc.? Are there any special efforts to keep rats or mice out of the storage container? What about protection from theft?

(8) Do farmers know about modern insecticides for grain storage, if and where they can be purchased, how much they cost? How do they know which insecticides to use on grain and the proper dosages? Are package directions followed?

(9) How do market prices vary to accommodate differences in grain quality? Is grain measured by bulk measure or by weight?

(10) How many types of grain do farmers store? Are they stored separately? Why? Approximately how much was put in storage at harvest this year? Last year?

(11) Do the farmers normally sell any of their grain? Or do they buy and how much? Is there a seasonal price variation? Could anything be done to take fuller advantage of the seasonal price fluctuation to increase farmers' grain sale profits?

(12) Do farmers ever store their grain together? Are there village or cooperative fields, storage or selling practices?

Section Q, Recognizing Storage Problems in the Field, gives some ideas for the use of this survey approach and the kind of conclusions which might be drawn to develop storage methods to ameliorate the problems revealed by the survey.

D. Developing a Strategy for Volunteer Involvement

There are four basic types of Volunteer postharvest project activities regardless of whether the Volunteers are working full- or part-time in grain storage.

1. Pre-extension investigation

The Volunteer investigates farmers' storage and drying practices, the variations, innovations, apparent success and shortcomings of each, and farmers' attitudes toward both postharvest losses and innovation. Investigation results will be used to plan storage improvements and extension programs.

2. Pre-extension improved storage method design and trial demonstration

Following the identification of popular storage methods and their apparent advantages and disadvantages, Volunteers begin to: closely observe the present methods and compare them to performance after a few simple improvements; assess the practicality of new or improved methods of drying and storage, e.g., solar dryers, metal bins, improved cribs, insecticides, etc.

3. General extension

When a specific method of drying, storing, or processing has been identified as advantageous in terms of cost, practicality, and farmer acceptance, Volunteers plan and execute program extension involving:

- the development of materials such as posters, radio spots, fair exhibits, farm-level storage demonstrations
- agricultural extension agent training
- development of materials delivery networks, such as materials transport organizations, insecticide ordering and supply networks, and credit programs for grain bin construction or grain purchase credit.

4. Grain storage and marketing cooperatives

Where there is potential for farmers' cooperatives for storing and marketing individually or cooperatively produced grain, Volunteers assist in: warehouse or bin construction, teaching proper bulk storage methods, teaching cooperative members the operation of the storage scheme and purchasing regulations, setting up record keeping systems, and promoting the formation of new storage and/or marketing cooperatives.

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D. DEVELOPING A STRATEGY FOR VOLUNTEER INVOLVEMENT contd.

This section includes job descriptions which give examples of these four basic types of storage projects. The activities in these different project types could be carried on simultaneously, evolve during the Volunteer term or service, or evolve over the course of several years, depending on the time available for Volunteer involvement, the advancement of host country interest, and the progress of the project.

The Peace Corps/VITA Small Farm Grain Storage Manual, Appendix E, "Working Paper on the Volunteer Role in Grain Storage," presents a practical discussion of problem assessment, storage method trial demonstration, financial considerations for program support, and extension strategies. It provides useful ideas for the programmer, trainer, or Volunteer who is developing a postharvest project.

Appendix A is the report of a recent grain storage programming mission for Peace Corps/Costa Rica, which may serve as a model for similar programming missions elsewhere.

JOB DESCRIPTION--PRE-EXTENSION INVESTIGATION

The Volunteer will:

1. Survey storage practices of representative or typical local farmers to determine storage and drying methods.

2. Maintain accurate records of all observations, following the predetermined techniques and format.

3. Investigate the variations in local storage and drying methods.

4. Identify areas of storage loss by interview, observation, and storage sampling.

5. Identify insect pests and the levels of infestation.

6. Determine cultural influences and labor divisions in grain storage and handling with particular note to the role of women.

7. Identify availability and cost of storage support materials such as insecticides, cement, metal roofing, new and used sacks, tar, etc.

8. Determine average storage capacities and relative proportions of grain for home consumption and marketing.

9. Investigate market price fluctuations and their influence on grain storage and marketing decisions.

10. Identify farmers with interest to experiment with improved storage methods.

11. Plan potential improved storage design trials, comparing improved storage methods to local unimproved methods.

JOB DESCRIPTION--PRE-EXTENSION STORAGE METHOD DESIGN AND TRIAL DEMONSTRATION

The primary role of Volunteer is to gather quantifiable data on traditional and improved storage methods in order to identify the most appropriate. The Volunteer will:

1. Construct or select for observation five models of each method to be assessed, e.g., basket and above cooking-fire storage; sealed gourd storage; unimproved crib storage; unimproved mud bin storage; crib with improved rat guard and insecticide treatment; and mortar-sealed mud bin storage.

2. Seek out, read, and review available reports from regional storage research and extension projects to assure the use of the most up-to-date information in the design and testing of local storage methods.

3. Use knowledge of storage principles in the design of improved storage structures.

4. Design and construct improved storage bins and dryers and alter existing storage structures.

5. Make regular, periodic observations of the level and type of insect infestation, the moisture content, and the general storage quality including evidence of rodent entry and depredation.

6. Draw samples from storage bins for analysis of typical storage quality.

7. Teach and supervise the application of fumigant and contact insecticides.

8. Discuss with farmers and extension agents their attitudes and perceptions of the storage methods under observation, with particular emphasis on each method's feasibility, cost, practicality, labor requirements, and performance.

9. Keep accurate records of all observations and measurements.

D. DEVELOPING A STRATEGY FOR VOLUNTEER INVOLVEMENT contd.

JOB DESCRIPTION--GRAIN STORAGE EXTENSION

The Volunteer will:

1. Meet with farmers on an individual and group basis to discuss the possibility of improved storage methods.

2. Teach extension workers and farmers the basic principles of storage, i.e., moisture and pest control and sanitation.

3. Assist farmers in the construction of new bins or dryers or the adaptation of existing storage structures.

4. Select farmers to operate model sites.

5. Organize farmers' visits to model storage sites.

6. Closely monitor model sites to assure proper use and maintenance of storage quality.

7. Develop visual aids and demonstration techniques in local language for use in schools; develop radio spots also in the local language.

8. Develop simple posters to explain proper use of insecticides, weed control around bins, use of rat guards, etc.

9. Give presentations to local school classes in basic storage principles and explain potential improvements over traditional storage methods.

10. Assist in the selection of farmer recipients for storage construction credit funds.

D. DEVELOPING A STRATEGY FOR VOLUNTEER INVOLVEMENT contd.

JOB DESCRIPTION--FARMER COOPERATIVE STORAGE AND MARKETING

The Volunteer will:

1. Identify existing farmer cooperatives with an interest in and sufficient capital to construct and maintain a storage warehouse.

2. Explain criteria for government or other grain buying credit.

3. Assist in the procurement and organization of transport of necessary construction materials and storage supplies such as metal roofing, cement, gravel, reinforcing rod, moisture meter, scales, burlap bags, and wood for construction of storage pallets.

4. Supervise warehouse construction to assure maintenance of quality standards and proper installation of rat proofing, moisture barriers, loading ramps, and adequate sealing of doors and air vents.

5. Train warehouse and cooperative managers in proper warehousing techniques including record keeping, storage hygiene, insecticide use, bag labeling and sampling techniques, stacking, and inspection.

6. Supervise the organization of market transport schedules.

7. Organize the transport of neighboring farmers to existing cooperative warehouse sites to discuss warehouse operation.

8. Develop simple posters explaining to farmer members the use of scales and credit payment schedules to build a common trust and understanding of the grain purchase and credit payment system.

9. Periodically review proper storage techniques with area warehouse personnel.

10. Periodically inspect the warehouses to insure proper stacking, hygiene, and repair of storage pallets.

11. Insure timely ordering and procurement of insecticide supplies for each storage season.

12. Establish and maintain grain market price records to assist area cooperatives in locating the highest price markets.

E. Determining Program Support Needs

The determination of program support needs, following the procedure set forth in Peace Corps Training Guidelines: The Program and Training Loop and a Systematic Approach to Training, can be broken down to four steps:

- Fiscal Preconditions, i.e., finances needed.
- Material Preconditions including whatever supplies, tools, equipment, and materials are necessary for the program.
- Personnel Preconditions including the supervisory, counterpart, and support personnel needed by the Volunteer program.
- Attitudinal Preconditions required in the client population and government support agencies to foster acceptance of program activities and initiatives.

The following preconditions checklist is provided as an example for a grain storage pre-extension program.

SAMPLE

PRECONDITIONS CHECKLIST
GRAIN STORAGE PRE-EXTENSION

Task	
1. Gather quantifiable data on traditional and improved storage methods presently in use to identify the most appropriate methods.	1. Access to farmers 2. Farmer interest 3. Portable moisture meter 4. Laboratory master moisture meter *See Section L 5. Portable scale 6. Cooperation of lab personnel 7. Insect identification chart 8. Sample collection bottles 9. Record book and evaluation forms 10. Bicycle or motor bike, access to repairs for transport, host country purchase and maintenance of transport

E. DETERMINING PROGRAM SUPPORT NEEDS contd.

2. Teach and supervise insecticide application in trial bins.	1. Cooperative extension agents 2. Cooperative farmers 3. Support of Grain Protection Bureau to order and transport insecticides 4. Supply of insecticides and fumigants 5. Insecticide duster 6. Hand sprayer 7. Burlap bags 8. Posters and instructional materials
3. Construct improved storage bins and solar dryer for trial demonstration.	1. Accessible, cooperative farmers willing to share costs 2. Cement, sand, gravel 3. Plastic sheeting 4. Transport for above 5. Shovel 6. Cement trowel 7. Hammer and nails 8. Wooden cement forms 9. Wood saw 10. Tape measure

F. Integration of Storage Project Activities with Rural Development Efforts

Volunteers may become involved in grain storage projects on an individual or group basis and as a full- or part-time activity. Many full-time projects will probably be initiated as part-time activities through the interest and involvement of individual Volunteers.

The increasing emphasis on programming for "Basic Human Needs" clearly includes grain storage as a priority area of development. As detailed in other sections of this Handbook, improvement of grain storage practices is one method for increasing the food supply. Increased production is interrelated to and inseparable from it. Therefore, Volunteers working in increased grain or food production projects should integrate some aspect of grain storage (whether that be extension, informal fact finding, field trials, extension agent training, etc.) into their work. They could do so during the non-growing season when there is no grain cultivation. In preparation for such work, Volunteers should be adequately exposed to the problems of grain storage in pre- or in-service training. Likewise, Volunteers primarily involved in grain storage might also integrate improved cultivation activities into their work role.

Furthermore, some rural Volunteer teachers could incorporate basic lessons on improved storage into their class presentations, possibly demonstrating with school gardens or fields. Storage activities could then become more full-time during the summer months. General community development Volunteers might begin storage activities by conducting an informal survey of local storage methods, farmers' attitudes, and apparent storage problems and needs. (Ideas for this type of survey are presented in Section C, "Investigating Local Storage Conditions.") The resulting information could be used as a basis for preliminary extension or field trial efforts. It could also be shared with other interested rural Volunteers or become the subject of an in-service session for grain storage training and project development.

G. Local and International Programming and Training Resources

Access to up-to-date, practical technical information and assistance is vital to the success of Volunteer efforts. Often there are excellent resources available locally with which the Volunteer should become familiar before seeking outside assistance.

Local sources of Information and Technical Expertise include:

- Farmers
- Extension agents
- Extension training centers
- Agricultural research centers
- Voluntary organizations involved in agriculture or nutrition
- Missionaries involved in agriculture
- Agricultural departments of a university or college
- Postharvest or plant protection bureaus
- Local offices of international development organizations such as:
  - Food and Agricultural Organization of the United Nations
  - United Nations Development Program
  - Bi-lateral aid organizations such as USAID, CIDA, FAC, SIDA, etc.
- The Peace Corps library and files

International sources of Information and Technical Expertise generally require more waiting time and possible communications delays if there is not a local office, but the potential benefits make it well worth the effort. The Volunteer should make requests as specific as possible, giving accurate details of the local conditions and the problem being addressed. International sources include:

G. LOCAL AND INTERNATIONAL PROGRAMMING AND TRAINING RESOURCES contd.

1. The Tropical Stored Products Centre
Tropical Products Institute
London Road
Slough SL3 7HL
Berks, England

TSPC is one of the oldest and most respected sources of technical expertise and information on post-harvest issues in the international development community. Technical experts from TSPC are stationed throughout much of the British Commonwealth. Requests for response to technical questions can be made to the above address. In addition, two very useful development-oriented publications are available from TSPC which should be subscribed to:

- Tropical Stored Products Information, a bulletin which includes reviews of recent storage developments worldwide and reports of related research and extension work. The cost is £ 1.25 including mailing. (N.B. There is no charge to official bodies in developing countries.)

- Tropical Storage Abstracts, a selection of recent abstracts relevant to the storage of durable agricultural produce in the tropics. The cost is £ .30 including mailing. (Again there is no charge to official bodies in developing countries.) Actual copies of the abstracted articles are not available through TPSC although names and addresses of the authors are furnished.

Both publications are available on request to:

The Editor, Tropical Stored Products Information
TSPC
TPI
London Road
Slough SL3 7HL
Berks, England

You may also be put on the permanent mailing list upon request.

2. International agricultural research institutes have a variety of resources available, some more involved in post-harvest concerns than others. They include:

o IRRI (International Rice Research Institute)
P. O. Box 933
Manila, Philippines

G. LOCAL AND INTERNATIONAL PROGRAMMING AND TRAINING RESOURCES contd.

- CIMMYT (International Maize and Wheat Improvement Center)
  Londres 40,
  Mexico 6, D. F.

- ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)
  1-11-256 Bequmpet
  Hyderabad 500 016 Andra Pradesh, India

- African Rural Storage Centre
  (IITA) International Institute of Tropical Agriculture
  PMB 5320
  Ibadan, Nigeria

The African Rural Storage Centre has undertaken research and training in small farm grain storage since 1973. Extensive research has been conducted on traditional and modified open storage cribs, and there are ongoing performance trials of various common insecticides. Short two- to ten-day training sessions are regularly conducted for regional agricultural personnel. Several Peace Corps storage training/orientation sessions have been held at ARSC. Arrangements for housing are available. Technical assistance is available to any African country, with an emphasis on West Africa to the Sahel. A regular newsletter and technical reprints are soon to be available. Information on all research and training is available on request.

3. VITA (Volunteers In Technical Assistance)
   3706 Rhode Island Avenue
   Mt. Rainier, Maryland 20822
   U.S.A.

VITA has a large number of technical Volunteer experts who respond to requests for technical information by mail. Peace Corps Volunteer requests for assistance should be sent to I.C.E. at the Peace Corps address below.

4. Peace Corps Office of Programming and Training Coordination
   Peace Corps
   806 Connecticut Avenue, N.W.
   Washington, D. C. 20525
   U.S.A.

This office has available to it specialists in agricultural programming and training who can, if the need warrants, travel on in-country programming missions.

G. LOCAL AND INTERNATIONAL PROGRAMMING AND TRAINING RESOURCES contd.

5. L.I.F.E. (League for International Food Education)
1126 - 16th Street, N.W.
Washington, D. C. 20036
U.S.A.

L.I.F.E. specializes in postharvest grain loss assessment and assessment training. It is also involved in supplying technical expertise in general nutrition-related areas of development.

6. Asian Productivity Organization
Aoyama Dai-ichi Mansions
4-14, Akassaka 8-chome
Minato-ku, Tokyo, Japan

7. Dr. N. S. Agrawal
Department Director
Ministry of Food, Agriculture and Irrigation
Krishi Bhavan
New Delhi 1, India

Both 6 and 7 above have extensive contact with long-standing, regional improved grain storage research, training, and extension programs.

PART II Grain Storage Project Training

H. Determining Training Needs and Priorities

Part II of this Handbook includes 12 separate training subject areas which may be utilized in a storage program training session or in Volunteer self-instruction. Although not all of these areas will be necessary for each storage program, at least a brief review of each section is recommended. Training emphasis will naturally be placed on the most crucial skill and information areas and their learning difficulty. This ranking of training need areas is derived from the Volunteer Task Analysis as set forth in Peace Corps Training Guidelines: The Program and Training Loop and a Systematic Approach to Training. Each separate task is rated according to three scales:

1. Degree of Importance

Extremely	1
Moderately	2
Marginal	3

2. Frequency of Performance

Daily	1
Daily to Weekly	2
Weekly to Monthly	3
Occasional	4
Seldom	5

3. Learning Difficulty

Extremely	1
Very	2
Moderately	3
Easy	4

Those tasks with the lowest total score will require the most intense training exposure. The following example of a Volunteer Task Analysis shows how training needs might be ranked for a grain storage pre-extension program.

H. DETERMINING TRAINING NEEDS AND PRIORITIES contd.

SUGGESTED VOLUNTEER TASK ANALYSIS

GRAIN STORAGE PRE-EXTENSION

	Degree of Importance	Frequency	Learning Difficulty
Technical			
I. Data Gathering--Volunteer will:			
A. Visit farmers to identify various storage and drying methods.	1	1	3
B. Determine labor requirements and division of labor for construction, maintenance and use of storage and drying methods encountered.	1	1	3
C. Draw random samples from drying and storage.	1	1	3
D. Take moisture measurements of grain samples.	1	1	4
E. Identify insect types and levels of infestation.	1	1	2
F. Classify rodent control measures.	1	2	3
G. Rate importance of rodent damage to drying and storage.	2	3	3
H. Select farmers to cooperate in supervision of later demonstration trials.	1	4	2
II. Insecticide Demonstration Trials--Volunteer will:			
A. Teach farmers and extension agents proper dosages and application techniques for insecticides.	1	3	2
B. Supervise the application of insecticides for trial demonstrations.	1	3	3
C. Keep records of insect infestation levels over a duration of trials.	1	3	3

H. DETERMINING TRAINING NEEDS AND PRIORITIES contd.

		Degree of Importance	Frequency	Learning Difficulty
D.	Draw samples from trial bins.	1	4	3
E.	Reduce sample size through sample quartering technique.	1	4	3
F.	Identify infesting insects in trials.	1	2	2
G.	Deliver insecticides to extension agents.	1	4	3
H.	Organize farmer group visits to demonstration trials.	1	3	3
I.	Discuss application, dosages, and costs with farmers.	1	3	3
J.	Assure prompt and timely repeat treatments.	1	2	2
K.	Identify problem areas in farmer and extension comprehension of dosage rates and application techniques.	1	1	3
L.	Design and develop instructional materials for extension agents and farmers.	1	4	2
M.	Plan and conduct one-day extension agent training courses.	1	3	2
III.	Improved Storage Demonstration Trials--Volunteer will;			
A.	Select farmers from the initial survey who are interested in having storage demonstration trials on their own farms.	1	4	2
B.	Identify three variables to test and demonstrate such as the use of insecticides, rat guards, improved shading, grain cleaning, bin disinfecting, etc.	2	4	2
C.	Arrange purchase and transport of necessary materials to demonstration trial sites.	1	4	2

H. DETERMINING TRAINING NEEDS AND PRIORITIES contd.

		Degree of Importance	Frequency	Learning Difficulty
D.	Visit and monitor trials on a bimonthly basis, recording moisture levels and infestation levels.	1	2	3
E.	Arrange area farmer group visits to demonstration sites.	1	3	3
F.	Initiate instructional discussions between farmers, visiting farmers and and extension agents.	1	3	2
G.	Calculate expenses and labor requirements of improved storage constructions.	2	4	2
IV.	Skill Transfer--Volunteer will:			
A.	Do task analysis for jobs of counterparts and clients.	1	4	3
B.	Establish learning objectives for counterparts and clients.	1	4	3
C.	Accurately determine skill and attitude levels of counterparts and clients.	1	4	2
D.	Design learning activities which promote the achievement of established objectives.	1	4	2
E.	Design and apply interim and post-evaluation devices to determine progress and success in achieving the objectives set. When necessary, modify/improve objectives and/or instruction.	1	4	3
F.	Design and conduct field evaluation to determine both relevancy of task analysis and training efficiency.	1	4	3

V. Cross-Cultural

A. Problem Solving--Volunteer will:

H. DETERMINING TRAINING NEEDS AND PRIORITIES contd.

	Degree of Importance	Frequency	Learning Difficulty
1. Solve problems in terms of self, other people, the physical and cultural environments. This involves:			
a) identifying needs and values of others	1	2	1
b) identifying his/her own needs and values	1	1	1
c) perceiving the cultural and physical environment--its potential and limitations--accurately, i.e., as perceived by the majority of people living in that environment.	1	1	1
d) using a systematic approach to problem solving.	1	2	2
B. Communication--Volunteer will:			
1. Set realistic goals that are consistent with physical and cultural environments.	1	3	2
2. Use a systematic approach to communication/skill transfer (see above).	1	2	3
3. Employ a communication process that effectively accounts for and is sensitive to both what he/she transmit to others and what they transmit to him/her verbally and non-verbally.	1	1	1
C. Goal Setting--Volunteer will:			
1. Set realistic goals that satisfy own physical and emotional needs and which are consistent with the physical and cultural environment.	1	3	2

H. DETERMINING TRAINING NEEDS AND PRIORITIES contd.

VI. Language

	Degree of Importance	Frequency	Learning Difficulty
A. Usage/Manipulation--Volunteer will, with increasing proficiency:	1	1	2
1. Master pronunciation so that speech is intelligble to native speakers.	1	1	2
2. Engage in polite conversation on a variety of subjects including:			
a) greetings and "openers"	1	1	4
b) living site/conditions, family members, marital status	1	1	4
c) offering and receiving of drinks, food	1	1	4
d) weather, time, health, food likes/dislikes, colors, numbers.	1	1	4
3. Discuss job-related subjects such as:			
a) type of storage and drying methods used	1	1	3
b) farmer attitudes toward losses	1	3	3
c) labor divisions and demands	1	4	2
d) storage costs	1	4	3
e) improved storage principles.	1	1	3

I. The Role of Grain and Grain Storage in the World Food Supply

Major Subject Areas

- Relative dietary importance of grain in developing countries
- Present and future demand for grain in local and regional food supply
- The postharvest segment of the local food supply pipeline

Training Objectives

- Volunteer will be able to discuss with farmers, extension agents, students, or village leaders the importance of postharvest conditions in improving the quality and quantity of the local and regional food supply

Suggested Resources

- FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas, Sections 1 and 2
- Chapters I-III, Post Harvest Loss Assessment Methods, American Association of Cereal Chemists, 1978. Available from 3340 Pilot Knob Road, St. Paul, Minnesota 55121, U.S.A.
- Statistics on local grain production, importation, and exportation (by region)
- Examples of grain and grain products common in local diet

Suggested Training Exercises

- Plan and prepare one meal with no grain, grain-derived, or grain-fed products
- Plan and prepare one meal with only grain and grain-derived products

Food storage, the setting aside and preservation of food for later use, is one of the major technological innovations that has enabled humanity to migrate to large cities and non-tropical climates where food does not grow all year long. Grain is one of nature's most easily preserved and nutritious food sources and has become the basic food staple for much of humankind. According to FAO, the diet in developing countries is comprised of 30 to 70% cereals.

The balance between food needs and the food supply has always been tenuous and has become even more important today, due largely to rapid population growth. We know that the world population will demand more and more grain in the years to come. Increased grain supplies can be provided in two ways: 1) by increases in production through the use of improved needs, fertilizers, machines and greater land cultivation, as well as the reduction of insect and disease problems before the harvest; and 2) through the reduction of postharvest waste and loss. Past development programs aimed solely at increased production have made only limited progress toward increasing the food supply; integrated programs to reduce postharvest losses have been much less common. For only recently has the problem of food supply been perceived as bearing two interrelated parts: production and postharvest storage and distribution. Storage is thus a vital link in the food supply the world over whether grain is stored in underground pits, in grain elevators, or on the rafters above cooking fires.

The development of some new varieties of rice and maize have had some interesting and unexpected effects on the food supply. Some new high-yielding or early-maturing varieties made it possible to increase production through double cropping. However, inclement weather during the new, earlier harvesting period has created new grain drying problems requiring new drying technologies to avoid consequent moisture-related losses. Furthermore, some of the new varieties of grain have either less insect-resistant seed coats or loose husks, opening the grain to potentially devastating insect attack. These new problems in the postharvest segment of the food supply clearly demonstrate the inseparable interrelationship of the two parts of this system. As a result, development organizations are continuing to find that it is of questionable value to encourage increased production without attention to postharvest considerations, particularly where postharvest losses are known to be significant.

J. The Movement of Grain from Harvest to Consumer

Major Subject Areas

- Major local postharvest stages including harvest, drying, transport, storage, shelling, processing and marketing
- Relative importance of postharvest pipeline losses at various stages
- Basic concepts of grain loss assessment

Training Objectives

- Volunteer will be able to outline the major stages of the local postharvest pipeline and will know the relative quantities of grain stored and marketed by local farmers and the quantity of national grain imports and exports
- Volunteer will demonstrate in-depth understanding of local postharvest stages including harvest, drying, transport, storage, grinding, preparation, etc., including approximate dates, labor requirements, and grain prices at harvest and pre-harvest.

Suggested Resources

- L.I.F.E./AACC Post Harvest Grain Loss Assessment Manual, Preface, Chapter I, II C. Available on request from L.I.F.E., 1126 - 16th Street, N. W., Room 404, Washington, D. C. 20036, U.S.A.
- Graphic illustration or chart of local grain pipeline, each stage labeled with total percent of grain which passes through that point, e.g., 25% marketed, 14% milled, etc.

Suggested Training Exercises

- Visit major local pipeline stage sites and follow with research to determine quantitative flow in individual stages of the pipeline for development of above-mentioned local pipeline chart
- Compile a list of 1) all products and bi-products manufactured from local grain and 2) local grain exports
- Spend a day at different grain markets to trace origin and destination of grain in each market

J. THE MOVEMENT OF GRAIN FROM HARVEST TO CONSUMER contd.

All grain consumed in a country is either grown there or imported. All grain must move to consumers (urban and rural) through what can be visualized as a pipeline composed of many reservoirs and interconnecting pipes. The structure of the pipeline can be very simple if most farmers consume all of their grain and sell none. Or, it can be very complex, including producers, wholesalers, retailers, processors, distributors, urban consumers, and the many phases of transport between these different groups.

The storage conditions in each section of the grain pipeline may differ widely, and leaks (losses) can and usually do occur in each section of the pipeline. Economically, it makes sense to find and reduce the biggest leaks in the pipeline to obtain the highest returns. However, cultural, political, and climatic influences may not always favor such a strategy.

In developing countries where the traditional small farmer produces the majority of the total grain harvest, it is common for as much as 80% of the small farm produced grain to remain on the farm or in rural areas. Consequently, that part of the pipeline is strategically the most important in terms of potential increases in the food supply. For this reason, focus on grain storage at the small farm level can often be the most promising and practical approach.

K. The Physical Properties of Grain

Major Subject Areas

- Three grain parts: pericarp, embryo, endosperm
- Bi-products of grain respiration and their effect on storage quality
- Control methods to retard grain respiration
- Relative humidity and equilibrium moisture content
- Moisture movement in stored grain

Training Objectives

- Volunteer will be able to explain to farmers and extension agents the three parts of grain and their role in nutrition and grain germination
- Volunteer will be able to explain to extension agents grain respiration, its bi-products, and the environmental factors which retard or promote it
- Volunteer will understand principles of equilibrium moisture content and will commit to memory the predicted local equilibrium moisture content for grain at time of harvest and at predominantly dry and wet season temperatures and humidity
- Volunteer will be able to explain to farmers and extension agents what causes moisture movement in grain bins and why stored grain should be shaded

Suggested Resources

- Peace Corps/VITA Small Farm Grain Storage, Sections 2, 3
- FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas, Section 4, Appendix H

Suggested Training Exercises

- Take hygrometer and temperature readings during two hour intervals throughout the day to demonstrate relationship of temperature and relative humidity
- Seal two samples of moist grain in separate jars placing one in a cool and the other in a warm environment to observe the collection of moisture over several days

* * *

Because the physical properties of grain play a vital role in its vulnerability and storage losses, a brief study of grain's physical structure and properties will give a clearer understanding of the major factors which cause such losses and the methods of their prevention.

Grain kernels are actually living organisms. If grain is to be used for planting, it must be kept alive. In addition, living grain resists storage deterioration better than dead grain.

All cereal grains--maize, rice, sorghum, wheat, barley, etc.--are actually fruit of the grass family Graminae. The structure of each type of grain is basically the same. The grain kernel consists of three parts:

- The seed coat, or pericarp
- The seed germ, or embryo
- The food storage reservoir, or endosperm.

The pericarp (seed coat) is waxy and acts as the grain's natural deterrent against the movement in or out of insects, mold, and moisture. The embryo (seed germ) extends up from the tip cap (the end of the kernel which was attached to the adult plant). The tip cap has many tiny pathways which connect to the embryo and the endosperm above it. Water passes easily through these pathways, causing the germination of the seed. The embryo, which will become the living plant, is readily destroyed by molds which attack moist grain. This destruction kills the seed so that it can no longer be used for planting. The endosperm (stored food of the seed) forms the largest part of the seed, about 80% in most grains. It is the largest source of the grain's food value for humans.

Like other living organisms, grain undergoes life processes. People breathe oxygen from the air and take nutrients from the food they eat in order to nourish their bodies and grow. Similarly, stored grain must maintain its life processes by taking in oxygen and converting the stored food in its endosperm to energy. This process is called respiration. Though the chemical reactions are rather complex, suffice to say here that when it is cool and dry, grain is dormant. This means that while life continues, biological activity is minimal, and there is no sprouting or growth. Nevertheless, the grain continues to slowly take in oxygen to convert its stored food into almost imperceptible quantities of moisture, heat, and carbon dioxide.

Two factors will serve to speed up the respiration process of grain: moisture and heat. Planting grain in favorable conditions of warm, moist soil will rapidly increase its respiration level, causing sprouting and growth in a matter of days. Grain moisture in fact influences respiration and grain deterioration more than grain temperature; an increase in moisture causes greater increases in respiration rates than comparable increases in grain temperature. The respiration rate of grain can be retarded by forced or natural aeration or by artificially cooling it, a process which in non-temperate climates is generally expensive and impractical. Reducing the moisture content of grain and cooling through natural aeration are generally more practical ways of reducing grain respiration.

The moisture content of grain will vary according to the climate in which it is grown and stored. Specifically, moisture content after maturity depends upon the relative humidity of the surrounding air. Relative humidity means the amount of moisture actually in the air compared to the maximum amount of moisture the air would hold at that temperature if it were saturated. Because warm air will hold more moisture than cool air, an increase in air temperature during the hot dry season, at midday, or in artificial dryers, will also lower its relative humidity. Air with a low relative humidity moving through high moisture content grain will cause the latter to give up moisture to the air. Warm the air and it does an even better job. This principle is used in the drying of grain. Conversely, grain may absorb moisture in the presence of air with high relative humidity. The equilibrium moisture content is the point at which the moisture content of the grain and air stabilize.

Different grains have varying equilibrium moisture contents at a different relative humidity. Research has determined that the maximum moisture for safe storage is the equilibrium moisture content for grain in climatic conditions with air at 70% relative humidity and a temperature of 27°C. A chart for various grain equilibrium moisture contents is found in FAO Handling and Storage of Grains in Tropical and Subtropical Areas, Section 4, page 53.

If grain is sealed in a closed container, such as a metal bin, the grain will reach an equilibrium moisture content with the air in the bin. Because there is relatively much more actual weight of moisture in grain than in air, it takes a great deal of air to appreciably increase the moisture content of grain. Thus, the air in a sealed bin quickly gives up its available moisture or picks up the little moisture available in the air and comes into equilibrium with the grain. Grain exposed to open air would come into contact with much greater quantities of air, thereby acquiring or losing much more moisture before coming into equilibrium.

If grain is not stored in a sealed container, e.g., in open cribs or hanging from the limb of a tree, its moisture content will continue to change in seeking equilibrium with the changing environmental conditions.

The respiration of grain releases heat, moisture, and carbon dioxide. The heat and moisture in turn further increase respiration, potentially causing a spiraling effect. Because both mold and insects reproduce more rapidly in conditions of warmth and moisture, maintaining low levels of grain respiration and consequently the reduction of grain moisture is a major component of safe storage procedures. In addition, both mold and insects produce heat and moisture through their life processes, further adding to the potential heat and moisture build-up. This phenomenon can cause serious pockets of heated, moldy, and insect-infested grain. We will look at this problem in more detail in Section M, "Factors which Threaten the Good Preservation of Grain."

L. Moisture and Its Measurement

Major Subject Areas

- Traditional non-mechanical methods of moisture measurement
- Mathematical formulation for moisture calculation
- Moisture removal methods of moisture measurements
- Electric moisture measurement methods

Training Objectives

- Volunteer will identify and become proficient in use of local traditional moisture measurement methods
- Volunteer will be able to use at least one method of local non-mechanical moisture measurement with maximum error of 2% ± safe storage level
- Volunteer will be familiar with use and maintenance of locally available moisture meters for field and laboratory use
- Volunteer will learn location of all publicly available moisture meters in his/her area

Suggested Resources

- Peace Corps/VITA Small Farm Grain Storage, Section 3, Appendix B
- FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas, Section 4
- Portable and laboratory moisture meters

Suggested Training Exercises

- Take moisture readings of grain at graduated moisture levels to become familiarized with operation of moisture meter
    - compare results to laboratory meter, sealing and labeling samples for transport
    - read repair manual and make trial adjustments to calibrate portable moisture meter with laboratory meter

L. MOISTURE AND ITS MEASUREMENT contd.

- Make non-mechanical estimate of grain moisture content using teeth, thumbnail, etc., and learn to gauge various critical moisture contents, checking against readings of moisture meter

* * *

Even though the reduction of moisture in grain is probably the single most important factor in its safe storage, there is no minimal fixed limit below which grain may be safely stored for any given period of time. Remember that a large insect infestation can produce moisture-related problems in spite of controlled temperature and adequate drying. The following table shows the approximate moisture content for up to one year's safe storage at 27°C and 70% relative humidity. Generally, above these limits moisture alone will cause deterioration; at or below these limits, it is possible to avoid moisture-induced losses.

Grain Type	Maximum Moisture Content for One Year (or less) Storage at 70% relative humidity and 27°C
Wheat	13.5%
Maize	13.5%
Paddy Rice	15.0%
Milled Rice	13.0%
Sorghum	13.5%
Millet	16.0%
Beans	15.0%
Cow Peas	15.0%

Source: Food and Agriculture Organization of the United Nations, 1970, p. 53, Handling and Storage of Food Grains in Tropical and Subtropical Areas.

The measurement of moisture is clearly vital to safe grain storage.

Traditional Non-Mechanical Moisture Measurement

Indigenous farmers have always had their own methods for measuring the amount of moisture in grain. Some of these methods provide a fairly reliable estimate of the grain's suitability for safe storage. These methods involve pressing the grain with the thumbnail, crushing it between the fingers, biting it, rattling a number of grains in a tin, smelling or shaking a handful, or plunging a hand with fingers extended into a large quantity of the grain (such as a sack). Wet or damp grain is soft, gives a dull sound, smells, and prevents penetration of the hand up to the forearm. With experience, one can do a fair job of judging whether or not the grain is suitable for storage.

Often, such local methods for determining moisture content are adequate to insure safe storage and should be used as often as possible. Mechanized moisture measurement techniques are considerably more costly, but they allow one to cut closer to the trouble line.

Other methods available for measuring moisture can be divided into those suitable for the laboratory or for the field. Laboratory methods are considerably more accurate, but seldom practical under field conditions.

Moisture Removal Methods of Moisture Measurement

Very briefly, the two most common of these methods of moisture measurement are oven-drying and distillation. Both methods are most commonly found in laboratories due to the complexity and fragility of the required equipment. In both methods the grain is first weighed on a very accurate scale. The sample is then ground into a fine powder and either heated in a special oven or in a special oil. Heating the grain causes the moisture to evaporate. If the oven method is used, the grain is again weighed, and the percentage moisture content can be calculated by the following formula:

$$\frac{\text{weight of moisture}}{\text{weight of wet sample}} \times 100 = \text{percentage moisture content}$$

The distillation method traps the evaporated water and condenses it into a graduated cylinder. The same formula can then be used.

Electric Moisture Measurement Methods

These methods rely on a piece of equipment called a moisture meter. These are commonly found at processing installations and warehouses, but they are generally too expensive and delicate for use by small farmers in developing countries. For this reason, their use is often restricted to extension agents. The most common and practical moisture meter for field use is the capacitance type. It measures the moisture of a given weight of grain by passing a current of electricity through it to gauge the conductivity which varies according to the type of grain and its moisture content. The reading of the meter is calculated on a scale with adjustments for grain temperature and type. Because capacitance moisture meters are liable to give false readings if the sample to be tested is wet on the surface, the grain should be held in a closed container for 24 hours before testing.

Resistance moisture meters may be of two types, using either a compression cell or a probe. In the compression cell method, a sample is compressed and the electrical resistance measured on a scale calibrated in percentage moisture content. Temperature correction is required. The probe method is less accurate but is useful where rapid evaluation of the approximate moisture content of a large, already bagged quantity of grain is needed.

Finally, the simplest and most accurate method of moisture measurement involves the use of non-iodized table salt and works on the principle of equilibrium moisture content. Its use is limited to determine whether maize has a moisture content of more or less than 15%, the maximum for safe storage of bagged maize. Consequently, it is not useful where closed system storage is in use. A small tightly sealed bottle of approximately 100ml is filled about three-quarters full of maize grain. About 5-10 teaspoons of free-running dry table salt are added, and the bottle is closed and shaken for a few minutes. (If necessary the salt may be dried in an oven or heated pan.) If the salt sticks to the inside of the bottle, the maize is above 15% moisture content. If it does not stick, the maize will be below 15% moisture content. This method is found to be accurate in measuring the 15% level within a 0.5% margin of error. It is more accurate than most other field moisture meters.

Information on specific types and brands of moisture meters can be found in the Peace Corps/VITA Small Farm Grain Storage Manual. Price and manufacturer's address are included. Generally, the use of moisture meters by Peace Corps Volunteers will only be necessary where careful observations are being made of local and improved storage performance and where artificial dryers are being tested and newly introduced. Moisture meters are rather delicate and should be transported with minimum exposure to shock and dust. Meters should be calibrated at least every six months, more often when they are used heavily, and especially when they are frequently transported. They can be calibrated by selecting several samples of grain at different moisture contents, measuring the moisture contents with a known accurate meter, probably to be found in a grain laboratory, sealing the samples in separate labeled jars and later compared to the moisture meter being calibrated. A variety of moisture contents should be checked, preferably at the level safe for storage of the grain in question, and 2% higher and lower than that level. Each moisture meter should come with instructions for re-calibration adjustments.

M. Factors which Threaten Good Preservation of Grain

Major Subject Areas

- The interrelationship of moisture, heat, insects, and mold in grain storage and grain loss
- Mold growth, its effect on storage and its control
- Insects, their effect on storage and their control
- Rodents, their effect on storage and their control
- Grain heating, its causes and effects on the storage environment
- Moisture, its movement and role in the storage environment
- Grain condition and its role in the storage environment

Training Objectives

- Volunteer will be able to discuss with farmers and extension agents the interrelationship of moisture, heat, insects, and mold in grain storage and grain loss
- Volunteer will be able to discuss and demonstrate specific methods which are or could be locally used to control moisture, heating, and mold growth (more specific information on insects, rodents, and grain drying is presented in Sections O, P and Q, respectively)

Suggested Resources

- FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas, Section 4
- Grain samples with heat; insect; mold; and rodent-related losses

Suggested Training Exercises

- Visit farm storage sites to identify five major storage threats
    - ask farmers what they think are the major threats to the storage of their grain

- **Present in local language summary of the interrelationship of moisture, heat, insects, and mold in grain storage and grain loss**

* * *

Grain can be stored safely anywhere in the world for more than 30 years with very little reduction of its nutritional value if three factors can be controlled. These three factors are moisture, heat, and pests. The relative significance of these factors varies according to climate. Heat, for example, is not a grain storage problem during the winter in Canada. Similarly, insects cause fewer problems in dry climates than in tropical ones. Safe storage practices basically entail manipulation of the environment to guard against storage threats. This can be accomplished through sealing dried grain in a moisture-proof bin, using insecticides, storing grain in cool, shaded areas, etc. Some forms of environmental manipulation will be more practical and effective than others.

Specifically, the principle causes of grain loss in storage area:

- Excessive moisture
- Heat
- Insects
- Mold
- Rodents

These causes are often interrelated and occur whether the grain is stored in small baskets on a farm or in huge warehouses in a major urban center. The basic principles involved in controlling and preventing storage losses are the same regardless of the quantity being stored. This Handbook deals only with control measures which are the most practical and available for use by the small farmer in the developing world.

Losses due to mold and insects are frequently interrelated, generally the most damaging to grain, and the most difficult to control.

Mold Growth, the Effect on Storage and Its Control

Microscopic mold spores (technically called fungi) are present on all grain kernels. When moisture content is too high (usually

14% or more) and the temperature is above 22°C, mold spores will germinate. The growing molds send out tiny thread-like roots (called hyphae) and produce a mass of new spores in a very short time. These hyphae pierce the seed coat, especially at the vulnerable seed tip cap, to feed off the embryo and the stored food of the endosperm. The molds will kill the seed germ and consume its stored food. Molds can penetrate very easily into damaged or broken kernels, which are unprotected by the waxy seed coat. Therefore, care should be exercised in shelling, threshing, and handling the grain to avoid its breaking or cracking. Moreover, although they do not greatly increase the moisture content of grain, molds produce a considerable amount of heat which can further promote the deterioration of stored grains by fostering additional insect and mold growth.

An obvious loss in quantity of the grain does not occur in the early stages of mold development, and reduction in quality is not immediately noticed. However, serious damage may rapidly occur in grains invaded by molds if they are not dealt with quickly. Molds produce chemical substances (called enzymes) which break down the grain and destroy the ability of seeds to germinate and produce new plants. They also cause both discoloration of the embryos and reduction in embryonic nutritional value. In the later stages of mold growth, the grain's stored carbohydrates and proteins are consumed, resulting in its loss of weight. Molds also cause chemical changes in the grains, which further reduces the food value and changes the taste of the grain.

In some countries there is growing concern about aflatoxins, chemicals produced by certain mold growth. Detection of aflatoxins reuqires very sophisticated laboratory procedures. Aflatoxins have been found to be highly carcinogenic. The most reliable way to avoid aflatoxin contamination is through drying of grain immediately after harvest.

Insects, Their Effect on Storage and Their Control

Insects feed on the stored nutrients of the grain and like molds, their metabolic processes produce heat and carbon dioxide.

The added moisture and heat make the grain a more favorable environment for the development of even larger numbers of insects and the growth of mold. The optimum grain moisture for insect multiplication is about 14-17%, but insects will grow and slowly multiply at moisture contents as low as 11%. Generally, insects do not reproduce in large numbers in grain that is below 11% moisture content. Most insects will go dormant or die in grain with 9% or less moisture content.

Temperatures also influence the growth of insects, which tend to die or migrate when temperatures are higher than 40°C. Because it is often costly or impractical to dry grain below 11% moisture content or to heat it above 40°C, chemical or indigenous insecticides are often used to prevent infestations. Details on the use of insecticides are presented in Handbook Section O, "Insects and Their Control."

Rodents, Their Effect on the Storage Environment and Their Control

Rats and mice eat large amounts of stored produce and often spoil uneaten remains. Characteristically, rodent damage can be easily detected in shelled maize which has the embryo eaten out, or in cob maize which is gnawed away to the base of the endosperm. Smaller grains are often totally consumed, carried away, or broken into many small pieces. Flakes of material partially eaten are indicative of mouse damage. Hairs, droppings, and tainted odors are common in rodent-damaged grains, reducing not the quantity of the produce, but its quality. On the world export market some countries refuse such contaminated produce.

The practical prevention of grain loss due to rodents involves:

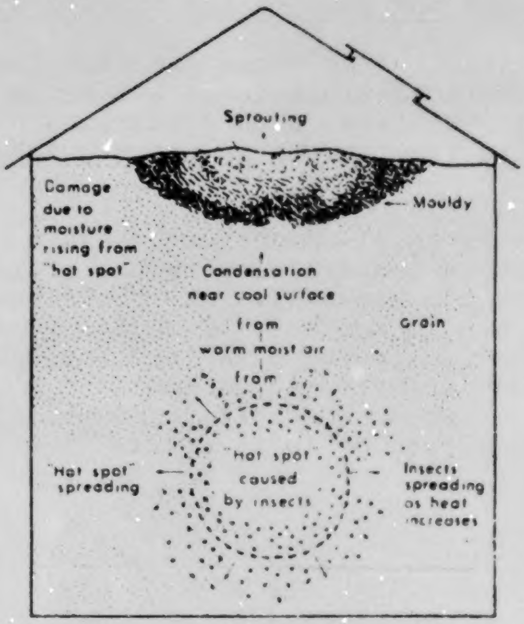
- o The use of storage bin construction materials that are impervious to the gnawing of rats and mice--metal, concrete, burnt mud bricks, etc.
- o The provision of conical metal rat guards fixed to the storage structure leg supports.
- o The use of chemical rat poisons or mechanical traps.

Grain Heating, Its Causes, and Its Effects on the Storage Environment

Grain is a good insulator, meaning that heat produced by mold growth, insects, and grain respiration tends to build up and concentrate in the grain mass. This build-up can result in what is called "a hot spot." (See Figure A) As insects tend to

M. FACTORS WHICH THREATEN GOOD PRESERVATION OF GRAIN contd.

FIGURE A


Sprouting
Damage due to moisture rising from "hot spot"
Mouldy
Condensation near cool surface
from
warm moist air
from
Grain
"Hot spot" spreading
"Hot spot" caused by insects
Insects spreading as heat increases

Spoilage of grain due to temperature differences, movement of moisture, and localized development of fungi and insects. "Hot spot" formation may occur at any location in the grain mass.

Source: Food and Agriculture Organization of the United Nations, 1970, p. 64, Handling and Storage of Food Grains in Tropical and Subtropical Areas.

migrate away from high temperatures, hot spot formation may actually spread infestation.

Heat produced by mold growth will increase until the molds are killed at temperatures of 50°C or more. At this point, bacteria and fermentation (souring) will continue to produce heat, and temperatures may exceed 80°C. These extremely high temperatures usually cause darkening of the entire grain kernel. Grain deterioration caused by the large amounts of heat produced by molds (and insects to a lesser extent) reduces the quality of the grain not only for food and feed use but also for industrial purposes of alcohol and starch production.

Moisture, Its Movement and Role in the Storage Environment

Well-dried and insect-free grain can keep for a considerable length of time if the conditions under which the grain is stored do not change. Unfortunately, such conditions can change as a result of temperature fluctations in the atmosphere outside the storage container.

Even when there is equal or uniform grain moisture distribution in storage, uneven temperatures in the grain mass (caused by the sun's heating of the bin walls) may cause moisture to migrate from one part of a bin to another. Internal moisture migration decreases grain moisture in one place and increases it in another. This frequently leads to mold-caused spoilage and insect growth in the high moisture areas. Understanding this externally caused process of moisture migration in the stored grain requires an examination of the actual influence of temperatures outside the storage bin.

In temperate climates, grains are placed in storage at relatively high temperatures. As the average air temperature outside the grain storage bin decreases with the changing of seasons, the walls of the storage bin are cooled, lowering the temperature of the grain and the air near the bin walls. When air is cooled, its density increases. Cool air has a lower volume and a greater weight than warm air. Since it is heavier, it tends to move down along the bin walls toward the bottom of the bin. This movement of cool air to the bottom of the storage bin causes the displacement of the warmer air that had been there. This warm air moves up through the center of the grain mass to the top of the bin near the central area of its cool surface. (See Figure B)

Changing the temperature of air changes the amount of water it can hold (i.e., its relative humidity, see p. 37). Thus the warm air rising through the bin carries moisture which will condense at the upper surface of the bins as its temperature is lowered by this cooler grain. The cooler, descending air will then be warmed by the grain, causing it to pick up moisture from the grain when it again goes through the center of the bin, depositing the moisture at the top of the stored grain when it is cooled once again. (See Figure B) This circular movement of air currents may deposit enough moisture at the top of the bin to promote mold and insect development and consequent spoilage if no countermeasures are taken. Once the molds and insects get started, they can spread to other parts of the grain mass.

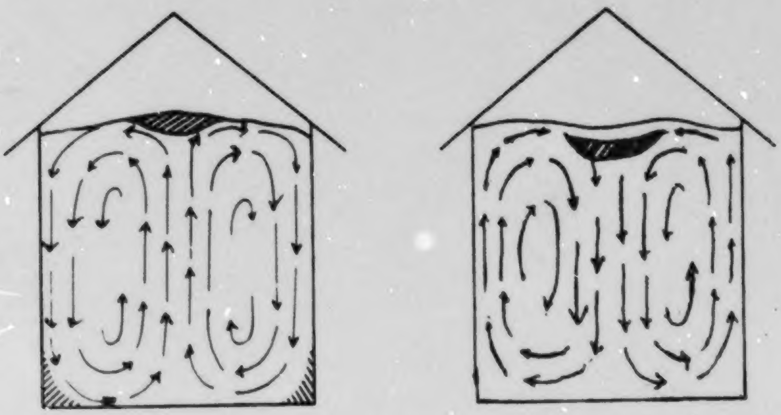
During the warmer seasons, the opposite situation may occur: outside air temperatures are higher than temperatures in the storage bin. The air near the bin wall is thus warmed and rises along the walls. The displaced cool air at the top of the bin moves down through the center of the grain mass. Moisture carried by the rising heated air will again be deposited near the top surface of the stored grain because moisture condensation is caused by the cooling of the air moving down through the cool grain mass.

This process of air and moisture movement caused by external changes of temperature is most evident where there are large grain masses and large seasonal temperature changes. However, it may occur also in situations where day-night temperature changes are great, particularly in non-shaded metal bins whose walls are good conductors of heat. Generally, this process does not occur in smaller bins. However, even in small metal bins of 3-5 tons, external heating may cause some moisture migration, build-up, and consequent grain deterioration if the bins are unshaded. Thus all closed bins should be shaded, particularly those made of metal.

Grain Condition and Its Role in the Storage Environment

The condition of grain at the beginning of the storage period affects the length of time grain can be safely stored. In addition to a favorable moisture and temperature environment, mold and insects require a readily available food supply. A sound, hard, seed coat helps keep molds and insects from easy access to the stored food of the grain. Sound kernels have better storage resistance than those that are cracked or broken. The presence of foreign material such as straw, weed seeds, and dust also contributes to the development of mold and insects. Straw and, to a greater extent, dust are particularly hygroscopic; that is, they tend to take up and retain moisture. Consequently, excessive dust and straw in storage may provide an environment conducive to the initial build-up of mold. Thus, grain cracking and breakage should be minimized in shelling, and all grain should be winnowed or sifted to remove chaff and dust before storage.

FIGURE B



Moisture movement within bulk of grain due to differences between outside air temperature and the temperature of the stored grain. Left, outside air temperature below grain temperature; right, outside air temperature above grain temperature.

Source: Dr. Henry Barre, Professor Emeritus, Ohio State University, Columbus, Ohio.

N. Grain Drying

Major Subject Areas

- Moisture content at grain maturity
- Drying methods (artificial, solar, and field drying)
- Maximum safe drying temperatures

Training Objectives

- Volunteer will be familiar with local drying methods and be able to discuss the relative advantages and disadvantages of each to farmers and extension agents
- Volunteer will be familiar with and able to discuss with farmers and extension agents the results of any local or relevant regional research on improved dryer design and performance
- Volunteer will be able to build and operate suitable dryer models for farmer extension

Suggested Resources

- Peace Corps/VITA Small Farm Grain Storage Manual, Sections 4 and 5
- FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas, Section 6
- Moisture meter
- Thermometer
- Solar dryer construction materials and tools
- Local research reports on improved drying methods

Suggested Training Exercises

- Build a solar dryer and monitor grain drying with thermometer, moisture meter, and non-mechanical moisture testing methods
- Compare natural drying methods and their drying rates to improved solar drying during simultaneous operation
- Dry samples of grain at increasing temperatures, then plant grain samples separately to observe effect on grain germination potential

N. GRAIN DRYING

- Use the same homogeneous bulk of grain to obtain each drying sample and plant one control which has not been artificially dried

* * *

The amount of drying required to prepare grain for safe storage depends upon its moisture content at the time of harvest. Grain drying practices also depend upon other considerations including the kind of grain, the method of harvest, the weather at the time of harvest, and labor availability during harvest.

In general, grain is fully mature at about 33% moisture content, at which point the growth process ends. The end of the growth process can be observed when the grain plant turns brown and dies. Generally, grain is harvested in tropical climates very soon after maturity to make way for the next crop. Harvesting and threshing of grain usually occurs when the moisture content of the grain is higher than is safe for closed storage.

Windrowing (i.e., drying in stacks or bundles) and field drying freshly harvested grain for even a few days with only a few hours of sunshine each day will remove large quantities of water. Field observations in tropical areas have shown that approximately ten days of field drying reduces the moisture content of grain from 35% to 24%. Such steps as field drying and shelling also greatly reduce the time and cost involved in artificial drying, if it is to be used.

Generally, the limitations to field drying are:

- Rodents and birds which consume and destroy large quantities of the grain. Insect infestation can get started in the unprotected grain.
- Rain and sun heating of the grain which cause grain deterioration.
- The relative humidity in some areas which is not low enough to permit thorough drying for safe shelled or bulk storage.
- Close-following rainy season, which forces rapid clearing of the field to prepare for the next planting.

Drying Temperature

Drying temperatures have a significant effect on grain quality. The maximum grain temperature advised during drying depends on: 1) the intended use of the grain, 2) the moisture content of the grain, and 3) the type of grain. For example, to assure a standard density of plants per hectare, grain used for planting needs to have a high germination potential. Because high drying temperatures kill the seed, air temperatures for drying seed grain must not exceed 40°C.

Excessively high grain temperature in maize and rice will cause increased kernel cracking, breakage, and discoloration and lead to a lowered food and market value of the grain.

The baking and milling qualities of grain are seriously reduced by excessive drying temperatures. Fortunately, grain to be used for such purposes can withstand higher temperatures than seed grain.

Maximum permissible recommended drying temperatures depend also upon the use for which the grain is intended. Examples are given in the table below. These are broadly recognized values not exclusively appropriate to all areas or varieties. Experience may indicate that temperatures in excess of these may be used satisfactorily. Initially, however, the temperatures listed are recommended. Minimum temperatures are always recommended when quality is a factor.

SHALLOW LAYER DRYER OPERATING TEMPERATURE CONDITIONS

Produce and Intended Use	Recommended drying temperature °C
Grain to be used for livestock feed	74
Grain for human consumption	57
Grain for milling and manufacturing	60
Seed grain or brewery grain	43
Rice for human consumption	43
Beans for human consumption	35

Source: Food and Agriculture Organization of the United Nations, 1936, p. 71, Handling and Storage of Food Grains in Tropical and Subtropical Areas.

Drying Methods

Grain drying methods which are practical for use by small farmers are field drying, natural ventilation, sun drying, and artificial, heated-air drying.

Field drying should be used to the maximum extent possible. The rate of drying of crops in the field largely depends on the atmospheric air conditions (temperature, relative humidity, wind, rain, etc.). Because of field losses due to dropping, spillage, rodents, birds, insects, anticipated rain and thievery, farmers may be obliged to gather the grain before it has been well-dried in the field. Where there are two growing seasons, the second following closely after the first, the early crop must often be harvested immediately at maturity to permit clearing the fields in preparation for the second.

Other drying practices such as windrowing and sun drying may be used to great advantage depending upon weather conditions and cropping patterns. However, they require much additional time and labor compared to direct harvest methods. Sun drying on mats, hard-packed earth, or other flat surfaces is commonly used in many countries. Because birds and other animals must be prevented from consuming the grain being dried, sun drying requires constant attention to assure good grain quality.

Open storage cribs designed to provide good natural ventilation are used traditionally when it is desirable to harvest food grains too moist for closed storage, or when artificial drying is not available or practical. It is especially common for the storage of unshelled maize on the cob. During the dry season, such storage may provide sufficient drying for shelling and later enclosed storage of the maize. Long-term open crib storage (more than 6-8 months) is seldom practical because such naturally ventilated structures in tropical regions offer little protection against infestation by insects and rodents or from rain and damp air during prolonged humid periods.

Heated-air drying systems consist of a drying bin to hold the grain through which heated (low relative humidity) air is passed, rapidly drying the grain. The use of these dryers is generally restricted to larger cooperatives due to limitations such as high cost of construction and maintenance. The fuel for heating the air (petrol, firewood, maize cobs, rice hulls) also adds to the cost further reducing the practicality of this system for individual farmers. However, this method can be used regardless of climatic considerations (rainfall or humidity); moreover, it is very fast compared to natural drying methods.

O. Insects and Their Control

Major Subject Areas

- Sources of insect infestation
- Basic insect biology
- Identification of major insect pests
- Selection of insect control methods
- Non-chemical and traditional insect control methods
- Control with chemical insecticides

Training Objectives

- Volunteer will be able to demonstrate and discuss insect infestation sources to farmers and extension agents as support for the deinfestation of bins and equipment
- Volunteer will be able to identify on observation the major local insect species
- Volunteer will be familiar with the life stages of the insect, and be able to identify the adult stages of major local species
- Volunteer will be familiar with and able to identify and evaluate all local insect control methods which do not rely on modern insecticides
- Volunteer will be familiar with major locally available insecticides and know which are or are not suitable for grain
- Volunteer will be able to recommend to farmers and extension agents the use of chemical insecticides, including dosages and application methods
- Volunteer will know the safety precautions for the application of all locally available insecticides for use with grains as well as first aid procedures for the treatment of insecticide poisoning

Suggested Resources

- Peace Corps/VITA Small Farm Grain Storage Manual, Section 6, Part 1; Appendix C; Section 7
- FAO Grain Storage and Handling in Tropical and Subtropical Areas, Sections 4, 5, 8, and Appendix C
- Degesch Principal Storage Pests, a color insect identification chart available from: Degesch, D-6000 Frankfurt (Main) 1, Postfach 2644, Federal Republic of Germany
- Regulations for local insecticide use
- List of all locally available insecticides and their suggested application and dosage
- List of government and private insecticide outlets and prices

Suggested Field Exercises

- Visit selected local farmers to practice insect identification and infestation level determination techniques
    - remove samples from all accessible parts of store, (i.e., top, bottom, sides) examining samples to determine type of infestation and desirability and type of treatment required
    - observe and discuss local insect control methods with farmers to determine farmer awareness and interest
- Visit area grain markets for similar insect identification and infestation level determination
- Practice the application of all local insect control methods
- Develop posters and simple instruction booklet for insect control methods extension
- Visit grain warehouse or dock storage to examine and practice bulk insect control methods

Insects represent one of the most prevalent and destructive causes of stored grain loss. In order to most effectively control them, a basic understanding of their physical characteristics and biology is required. Such information permits the correct use of insecticides as well as other more simple and less potentially dangerous insect control methods.

The choice of insecticides must reflect practical and economic considerations as well as an awareness of their potential dangers to the environment and to both the people using them and those who will eat the grain. Insecticides are poisons, some more dangerous than others. They are commonly misused, especially in developing countries, sometimes with tragic results. Such tragedies are avoidable through education. Because insecticides are often so vital to the success of a grain storage effort, it is critical that Peace Corps Volunteers know their proper use.

The Source of Infestation

Grain may become infested in a number of ways. In many grain-growing regions, infestation starts in the field before the crops are harvested. This is particularly true when the rice weevil and other insects are abundant in the field at harvest or where loosely constructed farm storage permits insects to move from stores to the fields or from unused grain bags back and forth to fields and nearby stores. Insects are generally more of a problem in tropical climates where they wait out the non-growing season in loose grain in the fields.

In addition to field infestation, there are several other important sources of infestation of stored grain. Grain is customarily stored in the same bins, sacks, or warehouses year after year. The cracks and crevices of wooden bins, for example, fill with dust and broken grain and afford places of concealment for insects. If these containers are never cleaned, insects later emerge in enormous numbers. Thus fresh grain quickly becomes infested.

Uninfested grain should not be placed for storage or shipment in sacks previously used for grain storage unless they have been insect-sterilized by heat or fumigation. Sacks may be heat-treated by boiling; sunning is also partially effective. On a thatch, sod or clay roof, it may be relatively ineffective. On a hot metal roof, it may be 100% effective.

O. INSECTS AND THEIR CONTROL contd.

In any discussion of controlling insects in grain, we need to recognize that the insects we are dealing with exist all over the world in other food and feedstuffs, in food refuse and in nature unrelated to people's grains and foods. These existed in nature long before there were stored grains. Because insects exist outside of stored grain, sanitation and the use of tight storage bins are extremely important factors in their control in grain stores. Unless each storage site is cleaned, the insects will be there waiting. Unless it is closed tightly, the insects will move in, and the grain will require repeated inspections and probably treatments.

Insect Biology

There are many control procedures available. Before selecting the best possible technique, an understanding of insects and the relation of controls to biological factors is essential. Insect control consists of a combination of many interrelated factors.

In the tropics beetles and moths are generally the most common insect pests causing losses and deterioration to stored food grains; in some areas termites and ants may also be a significant problem. Among the insects which live in stored food grains, a few begin their attack several weeks before harvest. There are other species which are unable to attack until the crop is almost dry or during the postharvest field drying period. As drying advances, certain of the insect pests are eliminated because there is no longer enough moisture available to support their needs. Insects do not breed successfully in an environment where the relative humidity is maintained at less than 40% or with temperatures below 10°C. As the temperature and humidity conditions diverge from the optimum, the time taken to develop from egg to adult increases, and the number of eggs laid become fewer. Some species tolerate the high humidity conditions with which fungi are associated, principally because they are mold feeders or require that the produce be decomposed by mold development in order to be suitable for them to eat. Most species do not tolerate prolonged temperatures above 42°C.

Insects have six legs. They have a hard outer skeleton or skin called the cuticle. The body is divided into three distinct regions: the head, the thorax, and the abdomen. In adult insects the head has mouth parts for biting and sucking, large compound eyes, and two antennae or feelers. The thorax carries the three pairs of legs and usually two pairs of wings. The abdomen contains part of the food canal and the reproductive organs. The adult insect lays eggs loosely in food, cements them onto food grains, or bores a small hole with its mouth parts in which an egg is securely laid. The egg develops and hatches a small worm-like larva, which is unlike the adult. The larva feeds, but in order to grow, it must cast or shed its skin in a process called molting. This process of feeding and molting continues until the larva has reached its maximum size. At this stage it stops feeding and may form an outer shell or in the case of moths spin a shelter or cocoon in which it changes shape and becomes a pupa. The pupa, which may look like a folded-together adult insect, remains immobile and does not feed; it develops into the fully formed adult insect which will push or bite its way out of the covering.

Since it is very difficult to see the eggs or the very young larvae of insect pests, and since they do not leave large holes in the grain, the farmer may assume that grains and kernels are uninfested. However, the presence of a few adult insects walking on or flying over stacks or bulks of produce usually indicates that there are many more insects inside the bulk of grain.

Under good conditions insects breed very quickly, the life cycle from egg to adult being completed in a few weeks and each female insect laying a large number of eggs. Under ideal temperatures and humidity (28°C and 65-80% relative humidity) and with adequate food, a pair of flour beetles is theoretically capable of increasing to millions in six months.

Identification of Major Insect Pests

With some careful practice, Volunteers can learn to identify the most common insect pests. Local entomologists or plant storage protection officers are likely sources of information and instruction. The Peace Corps/VITA Small Farm Grain Storage Manual has black and white pictures of common grain insect pests, and both the Degesch color insect chart and the FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas may be helpful for Volunteers who wish more detailed information. For identification purposes it is best to place dark-colored insects on a light surface such as a piece of white paper.

Selection of Insect Control Methods

The selection of a control method is influenced by many factors:

- Temperature
- Moisture
- Type of storage
- Type of insect

- Length of storage
- Price of grain and insect control.

Temperature

As already stated, insect pests of stored grain have certain temperature and moisture requirements which directly affect their proliferation as well as their ability to damage grain and resist chemical control. As a group, grain-damaging insects are mostly of subtropical origin and do not hibernate. They have developed little resistance to low temperatures so that in cool areas they are rarely abundant enough to cause serious damage to stored grain. Temperatures that are not immediately lethal indirectly do cause the death of many insects by rendering them inactive and preventing them from feeding.

While each species has its own low temperature dormancy level, most of the grain insects slow down appreciably below 15°C. This also means that the uptake of fumigants or other protectants is slowed, and higher dosages are required. Moreover, the insects will move back into cracks and crevices and become less active. By 10°C, while the insects are not technically dormant, activity is further depressed and mating and egg-laying usually stop. At 5°C true dormancy occurs. However, mites continue to be active down to 5°C if the moisture level is favorable.

Subject to certain upper limits, the rate of development and reproduction of all grain-infesting insects increases with rising temperatures. A grain temperature of 21°C is considered to be favorable for insects. At 21°C or higher, severe damage to stored grain from insects may be expected whereas below 16°C serious damage is not likely to occur. Temperatures above 35°C shorten the adult life span and are unfavorable for the reproduction of most grain-infesting insects. Temperatures above 38°C cause the death of some insect pests, and temperatures of 60°C kill them all.

Moisture

Grain moisture is an important factor in the life of insect pests because they depend on their food supply for the moisture needed to carry on their life processes. Up to a certain point, increasing the grain moisture favors a rapid increase in the number of insects. Beyond that point, microorganisms take over and destroy them, except the fungus feeders. At the point that microorganisms take over, the affected grain is totally destroyed as well. If the moisture content of the grain is low, the water required for carrying on vital life processes must be obtained by breaking down the food reserves in the fatty tissues of the insect's body.

Moisture requirements differ with different species of insects. Weevils are unable to reproduce in grain with a moisture content below 9%, and the adults soon die. Adult rice weevils normally survive for only one week in 8% moisture, wheat at 29°C; at 9% moisture, about 70% die by three weeks, and few live for more than seven.

Type of Storage

Storage types can be broken down to closed and open storage systems. Sealed gourds, metal bins, barrels, undergound pits, and some mud bins are examples of closed systems. Open systems are generally more varied including thatch baskets, open piles, bunches hanging from trees, and piles above cooking fires. Note that closed systems are not necessarily hermetic.

Closed systems keep insects already infesting the grain from escaping and keep insects outside the storage container from entering. Open systems permit the movement of insects in and out of the stored grain. Open systems are most common in areas of high humidity where grain does not dry naturally to levels low enough to permit closed system storage without danger of mold growth and rot.

Closed systems permit the use of both fumigants and contact insecticides while open systems can only be treated with contact insecticides unless they are enclosed with some type of gas-tight envelope such as a plastic tarp, which permits fumigation. Fumigation of open storage systems without the use of some form of gas-tight envelope is not only ineffective in killing insects in the grain, but also can be lethal to people and animals.

Insect Type

The type of insect pest infesting a bulk of grain will sometimes determine the type of control method to be used. In general, fumigation and airtight storage is effective against all types of grain-infesting insects. The Angoumois grain moth, because it can only penetrate some 10 cm into the grain mass, can be controlled by a surface spraying or dusting with a contact insecticide. The insecticide information sheets in the Peace Corps/VITA Small Farm Grain Storage Manual gives details of the insects controlled by some of the most common insecticides.

Length of Storage

Grain which farmers intend to store for only a few weeks or even up to three or four months may not require any form of insect control other than the standard measures of cleaning the grain containers and good sanitation measures around the storage sites. Local farmers often know how long grain can be stored without insecticides before major infestation build-up. This is often the time when farmers decide to sell their grain, passing the impending infestation problems on to someone else. Ideally, to reduce insect-caused grain losses throughout the entire pipeline, insect control measures should be applied to all stored grain when it is first put into storage. However, this is not always in the economic interest of the farmer. If grain is to be stored by the farmer for three months or more, insect control measures such as the use of insecticides or airtight storage are generally required from the time the grain goes into storage. Grain is treated far more effectively when it is first put into storage than after the infestation level has built up during the first few months.

Price of Grain and Insect Control

The economics of insect control are difficult to accurately calculate due to the difficulty of projecting the estimated grain and financial losses due to expected insect infestation. On the other hand, the cost of one or repeated treatments per ton of grain, including labor expenses, can be readily calculated. This cost may then be compared to the equivalent quantity of grain of the same value. Farmers will often find this to be the most persuasive argument in favor of insect control, as the cost of insecticide per ton may be very favorable. It is certainly worth comparing the cost of various alternative insecticides to insure that farmers are using the most economical chemical, keeping in mind the relative effectiveness of each chemical.

Insect Control Measures

Except for the mixing of clean grain with infested grain or the presence of nearby materials literally crawling with insects, infestations usually start at a comparatively low level. Even under favorable temperature and moisture conditions, a second generation of insects takes about a month to become active and start multiplying. The essence of preventing insect-caused losses to grains is to prevent the infestation from the start. Note, however, that complete exclusion is almost impossible in most countries today.

Good Housekeeping

Sanitation on the farm in dryers and silos will do much to prevent infestation and to reduce losses. It is essential that clean, insect-free, and weatherproof storage be provided from the very beginning and that nearby sources of infestation be eliminated.

Concrete bins and metal bins with tight seams are readily cleaned. Wooden bins or loose metal sheathing around sacked grain need to be cleaned as thoroughly as possible and then sprayed with an appropriate insecticide. Refer to the Peace Corps/VITA Small Farm Grain Storage Manual for information on insecticides for the treatment of storage sites and bulk grain. When cleaning and before spraying or dusting, remove all waste grain and feedstuffs. Be sure to clean out any machinery no matter how simple or complicated. Remove all residue from the premises, use it for feed or burn or fumigate it.

Dockage, which includes chaff, broken stems, husks, grain dust, and other impurities, greatly encourages the development of insects in stored grain. Dockage also tends to absorb and retain moisture and prevent aeration. Thus, it must be screened or sifted out before storage.

Making the Storage Container Weathertight

Any holes in the roof should be repaired to prevent rain from entering. Windows, vents, and evacuation shoots should be provided with means for closing during periods of rain or designed to prevent rain from entering. Doors should likewise be protected. Good drainage should be provided around the exterior of the building, away from the storage container, particularly at the joint between the walls and the floor to prevent seepage from beneath the floor.

Areas surrounding storage facilities should be maintained free of accumulated debris, grain and grain product residues, and equipment. This should be a part of the routine housekeeping program. Furthermore, at least one meter around the entire storage facility should be kept free of vegetation. Such measures will also help control rat infestation.

Bags should preferably be stored up off the floor on wooden supports or be hung from the ceiling or roof. They too need to be cleaned and treated with insecticide before use. The Peace Corps/VITA Small Farm Grain Storage Manual gives details on the construction of sack storage pallets. Sanitation in a warehouse means stacking sacks 60 cm away from the walls so that inspections and cleanings can go around the entire bulk of grain and so that fumigation tarps can be properly sealed. Sanitation in warehouse storage means cleaning floors whenever a lot is moved and before another is stored in its place. It means a constant cleaning and policing of the building and of the surrounding area so that the problems due to insects from nearby residues and debris will be kept to a minimum.

Insecticide Treatment of Storage Facilities and Grounds

Insecticide treatment of storage facilities and grounds will be of little help in insect control unless the areas are first cleaned so that the chemicals can reach the structures and grounds themselves. Walls and other structures covered with dust and debris can be treated with pesticide chemicals only by applying them in excessive amounts.

Insecticides can be brought into contact with insects in two ways. First, insecticide sprays or dusts may be mixed with grain or applied to room areas and surfaces such as walls, floors, etc. The insects walk over the surface and thus contact the insecticide. This type of application is commonly referred to as residual spraying or dusting, especially if the specific contact insecticide used remains effective for a long period of time. Secondly, an insecticide may be released into the atmosphere as a gas. This method is referred to as fumigation.

Many insecticides are available though relatively few are safe for use on stored grain and it is important that the appropriate ones be used. This is true not only from the standpoint of effectiveness in controlling the insects, but also from the standpoint of human safety. All pesticide chemicals are potentially dangerous, especially those related to food product storage. Therefore, the least hazardous chemical should be chosen.

Residual insecticides are commonly available in two forms: liquids and dusts. The dusts may be in the form of powders, either directly applied to surfaces or mixed with water and sprayed on. The liquids are usually diluted with water or highly refined oils for application. They are generally applied by either hand-operated pressure sprayers or motor-drive pump units. For vertical surfaces they should be diluted to the point when the liquid would begin to run down the vertical surface. On horizontal surfaces the spray should not form puddles or pools.

In treatment of storage facilities such as bins and warehouses and the surrounding areas, the following materials and procedures are recommended:

Pesticide Chemicals

1) 1/2 liter 57% malathion emulsifiable concentrate in 16 liters of water, or

2) 1 liter 25% methoxychlor emulsifiable concentrate in 8 liters of water, or

3) 1-1/3 liters of 6% pyrethrin with 60% piperonyl butoxide in 16 liters of water.

Procedures

1) Spray 8 liters of diluted insecticide per 100 square meters of surface area.

2) Spray the inside of cleaned walls of buildings to at least a height of 2 to 2-1/2 meters, or higher if easily reached with the sprayer. This is especially important if walls are rough-textured or have numerous cracks or joints in them.

3) Spray cleaned floors of storage areas giving special attention to the areas along wall-floor junctures and cracks of joints in the floors which may harbor insects.

4) Spraying on the exterior of the building should include:

    a) the grounds, to a distance of about 2 meters from the building.

    b) the pillars (or supports), if the building is raised off the ground, and an area of a few feet around the underside of the floor at the support.

    c) the entire underside of raised wooden or concrete (if in poor repair) floors.

Frequency of Treatment

1) Metal bins with caulked seams can be cleaned so as to leave almost no food or insect residues. Spraying with malathion or methoxychlor about two weeks prior to placing new grain crop in the bins should be sufficient treatment for the structure. From then on, watch the grain.

2) Wood, mud, or thatch bin cleaning is more difficult and is often less complete. Spraying of the bin with malathion or methoxychlor should be accomplished each time before the bin is filled with grain.

3) Warehouses should have walls, floors, and overhead areas thoroughly sprayed once each year prior to receiving the new crop. In addition, whenever stacks of grain are fumigated, the floor and wall areas surrounding the stacks should be sprayed immediately prior to the fumigation. When the fumigation tarp is removed, insects harbored in and on the walls and floor will otherwise cause reinfestation problems. Whenever a storage bag or area is emptied, the area should be thoroughly cleaned and sprayed using an appropriate insecticide before any other grain is stored in the area.

Insecticide Treatment of Bags (Sacks)

A major problem in many regions is the handling of grain, feeds, and cereals in used bags. All woven bags, whether burlap or polypropylene, will harbor insects. Plastic bags will be less of a problem than burlap, but they too hold grain debris between and among the fibers, in the weave, and at the seams, where insects live and feed.

It is impossible to clean burlap or polypropylene bags. When they are employed for grain, they should be treated with insecticides to kill the grain insects harbored in them. While it is true that grain insects can be killed by exposure to 60°C for ten minutes, real care is required to attain and maintain this temperature by the usual sun-heating procedures. In many rural areas a fairly good job is done by spreading used bags as well as grain in the sun on roofs, parched land, or patios, but usually not all insects are destroyed. In addition, some of them are merely driven into the soil or into the buildings under the roofs and remain in the area as a potential reinfestation problem. Consequently, the only completely reliable treatment for woven bags is by means of pesticide treatment or boiling the bags in water. Boiling has the possible disadvantage of weakening certain types of burlap or plastic weave bags. A few sacks should be pretested to determine any negative effects of the boiling before treating large lots of used bags.

Non-Chemical and Traditional Insect Control Methods

There are a variety of traditional methods to control insects in stored grain, including sunning, the mixture of certain crushed or ground plants with the grain, the mixture of sand or wood ash, smoking grain over cooking fires, storage in airtight containers, and the storage of unthreshed grain with the insect protectant husk left on. The Tropical Stored Products Centre in Britain has done extensive investigations into the use of such methods and is an excellent resource. Specific subject requests for information should be addressed to:

Tropical Stored Products Centre
Tropical Products Institute
London Road
Slough, Berks SL3 7HL, England

The Peace Corps/VITA Small Farm Grain Storage Manual gives more detail in the use of the above traditional storage methods in Section 6, Part 1. Additional details may be found in Section 8 of the FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas.

The function of various traditional insect control methods is not always clearly understood due to the unknown properties of the wide variety of local plants which may be mixed with stored grain. There is also a distinction between methods which actually kill insects and those which inhibit infestation by driving insects out of the grain or making it difficult for insects to attack the grain. Methods which actually kill the insects are generally preferable although infestation inhibitors should not be overlooked or discounted.

Sunning grain kills some insects and drives others out of it. A 9% moisture content or less in grain (i.e., in very well-dried grain) will kill most insects or cause dormancy due to lack of adequate moisture for reproduction.

The mixture of certain local plants in ground, crushed or powdered form functions as an insecticide and/or an insect inhibitor. Others, though traditionally used, may have little appreciable effect. Research needs to be done in this area as it is conceivable that effective insecticides can be derived from these traditionally used plants. (It is suggested that the Peace Corps Volunteer actually try out the method in some grain kept under his/her control before recommending for general use.)

The mixture of sand or wood ash with grain acts as both an insecticide and an insect inhibitor. The sharp edges of the sand or wood ash scratches the waxy coating of the insect's body causing it to lose moisture and dehydrate. This method is only effective as an insecticide when used with dry grain at 9-10% moisture content or less. If used in more moist grain, the sand and wood ash function as inhibitors by filling the inter-granular spaces in the grain bulk, and slowing the movement of insects from one grain to another.

The smoking of grain stored above cooking fires is effective through the continual drying and heating of the grain, which are both insecticidal and insect-inhibiting. The smoke itself may be insecticidal in very heavy concentrations though more likely it is simply an insect inhibitor.

There are many forms of airtight containers, though they are traditionally rather small and often restricted to seed storage. Gourds may be sealed with tar or resin. In some regions the use of oil drums and kerosene tins is becoming increasingly more common as a form of airtight storage. Some underground pits may be airtight as well. Airtight containers are insecticidal, killing off all insects through gradual asphyxiation. The build-up of carbon dioxide and the depletion of oxygen is a gradual process which will depend on the number of insects in the grain, the grain moisture content and its respiration level, and the volume of the container not filled with grain. Generally, the asphyxiation of insects will occur after about four months.

The storage of unthreshed grain is common for both maize and rice, where the natural protection of the husk offers insect-inhibiting advantages. Neither maize or rice husks completely shut out insect infestations although they are significantly more effective than storing husked grain without insecticide. The development of new maize varieties which have looser husks has brought about new storage difficulties as insects find much easier access to the grain kernels through the more penetrable husks.

Insect Control with Chemical Insecticides

There are many chemical insecticides which effectively kill insects. However, there are relatively few which are safe for use on stored grain or in association with any food product. As discussed earlier there are contact insecticides which may be in the form of liquids or dusts diluted before application, dusts applied directly, and fumigant gases. The number of insecticides which are locally available may be large and varied though

O. INSECTS AND THEIR CONTROL contd.

those which are suitable for grain storage will be much more limited. Insecticides not intended for use on food products are commonly misued in grain storage. Volunteers may find that this is a major local problem requiring immediate attention. The insecticide information sheets in Section 6 of the Peace Corps/ VITA Small Farm Grain Storage Manual gives application dosages, trade names and insects controlled by seven of the most common insecticides recommended for use in stored grain, in grain storage equipment, and in storage buildings and surrounding areas. Details are provided for a much wider variety of insecticides in Appendix C of the same manual. When in doubt as to the recommended dosage, application method, or safety of any insecticide, contact the local government office in charge of plant protection or grain storage. Do not rely solely on the judgment of private insecticide outlet salespersons as they may be misinformed or inclined to provide information which would increase their insecticide sales. Insecticides should always be clearly labeled with dosage and application instructions as well as their composition. Insecticide containers should never be reused for any type of food storage or preparation or water vessel. Insecticide dosages should be carefully respected, keeping in mind that increasing the dosage may not only be costly, but also dangerous.

Instructions for dusting, spraying, and admixing insecticides and for grain fumigation are included in the Peace Corps/VITA Small Farm Grain Storage Manual. Precautions for the treatment of poisin victims should be included in instructions to extension workers, farmers, and Volunteers.

P. Rodents and Their Control

Major Subject Areas

- Principal rat species
- Rodent food consumption needs and patterns
- Basic rodent biology
- Rodent-proofing
- Rodent poisoning
- Rodent trapping
- Rodent fumigation

Training Objectives

- Volunteer will be able to identify local rodent species
- Volunteer will be aware of basic rodent biology and be able to convincingly discuss the rationale for control of rodent food supply as the most successful long-range rodent control measure
- Volunteer will be aware of trapping procedures and be able to demonstrate the use of locally available traps
- Volunteer will be completely familiar with locally available brands and types of rodenticides, their prices, distributors, application dosages, and hazards
- Volunteer will be able to supervise rodenticide application and be fully aware of dangers and limitations inherent in rodent poisoning methods

Suggested Resources

- Peace Corps/VITA Small Farm Grain Storage Manual, Section 6, Part 2
- FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas, Section 9
- Rat and mouse traps available locally
- Rodenticides available locally

- Rodent fumigation equipment
- Living or dead rodent specimens of common local species

Suggested Training Exercises

- Visit farm storage sites to identify rodent runs and infestation levels
    - Discuss rodent infestation and control methods with farmers
- Practice use of traps, rodent-proofing, poisoning, and fumigation

* * *

In spite of rodent control efforts dating to biblical times, even today the rat population in any area is roughly equivalent to that of humans. The genus Rattus has 570 named forms--more than any other genus of mammals. The Norway rat (Rattus norvegicus), the roof or black rat (Rattus rattus), and the house mouse (Mus musculus) cause the most extensive damage. Economic losses due to rodents are so large and so widespread that they defy precise estimation.

Rodents will gnaw through almost any object in their path to obtain food or shelter and to wear their incisors, which grow continuously--about 10cm per year in the Norway rat. Damage varies from place to place and year to year and fluctuates with changes in rodent populations. An eruption of rats occurred in the Philippines during 1952-54 resulting in a reported 200 to 2000 rats per hectare. Losses totaled upwards of 90% of the rice and 20 to 80% of the maize crops.

Rats eat about 10% of their body weight in food each day and contaminate a great deal more with their droppings and urine, rendering grain unfit for human consumption. It is impossible and undesirable to make a distinction between storage rodents and those in the total environment. They move in and out of humans' immediate ecology. This resiliency is precisely what makes them such formidable enemies.

Rodent Biology

Preventing losses to or contamination of stored food grains by rodents depends upon four factors: environmental distribution; the pressures of the population; migration and transportation into controlled areas; and population dynamics and biology. The life of the average rat or mouse is fairly short, and the young mature rapidly. The gestation period of the Norway and roof rats is 22 days, and that of the house mouse is 19 days on the average. Female rats and mice can mate within 48 hours after they have borne young. If a female is nursing young and is also pregnant, birth of the new litter may be delayed by as much as a week.

Large litters are the rule though frequently some of the newborn are killed and eaten. Disturbance of the nest by other rodents may cause litter destruction either by the mother or by the invaders. If the nest is disturbed, the mother may move the young, which reduces their survival rate. For about three weeks, the young depend entirely upon the mother for food. They begin to take solid food in the middle of the third week. They can then live away from the mother if necessary. Reproduction can occur at the age of two to three months.

There are daily patterns of activity among rats and mice. When food is abundant, the rat shows the greatest activity during the first half of the night, becoming most active at or shortly after dusk. This activity continues until about midnight. The house mouse has a similar pattern of nocturnal activity, and has a second, lower activity peak starting well after midnight and lasting until dawn.

Rats and mice often carefully avoid strange objects, even strange food. This reaction is the basis for many beliefs about the "wily" and "intelligent" rat. Rats may avoid a new food for several days, and when they do begin to eat it, they may do so only in small quantities. If such amounts contain a sublethal dose of a poison that only makes a rat sick, the avoidance reaction is strengthened. This is the biological basis for prebaiting with unpoisoned bait before poison is added.

Roof rats and the house mouse are notoriously good climbers. They can climb any vertical surface where they can get toenail holds. Rats can reach 30cm up a wall. They can also do a standing high jump of almost 60cm, and with a running start and a bounce can clear nearly a meter. Therefore, allowing for a safety factor, the clear distance for rat guards should be a meter. The house mouse can do a running jump of 60cm. Rats and mice are good swimmers and can pass through drains, under water, and through sewers.

Rodents will nest in any safe spot close to food and water. The Norway rat is a good burrower; the roof rat prefers the upper reaches of structures. Mice will burrow or not, depending upon the nesting availability. Rats can tunnel down two meters in soft earth. Rats digging underground along a wall will keep close to the wall, unless they meet an obstruction. The construction of a horizontal lip underground extending out from the wall will force them to give up and stop their digging.

Rodents will eat almost anything, but do have decided preferences. They like meat, grain, grain products, eggs, and potatoes. Rodents have an excellent sense of touch through their face whiskers and longer guard hairs over the body. Vision is not as well developed as is that of humans, and they are color blind. They have a keen sense of smell, recognizing other rats, rats of the opposite sex, and strange rats.

The Peace Corps/VITA Small Farm Grain Storage Manual, Section 6, Part 2, gives details on species variations with diagrams of the Norway rat, the roof rat, and the house mouse. A diagram for the identifcation of rodent droppings is also included.

Since rats and mice generally occupy only a limited area, they may use the same pathway many times. Outdoors or on earthern floors, these runways may appear as clean-swept, well-packed paths 5 to 8cm wide. In dusty areas, runways may consist of tracks made in dust by passing rats or mice. In many areas, rats and mice leave dark smears or marks from the natural oils and dirt on their bodies when rubbing against objects. Mice runs may otherwise be difficult to locate because they are small and often very faint.

Rodent-Proofing

The rodent-proofing of each individual structure or bin presents its individual problems. Rodent-proofing should be custom-designed for each structure. First, the exterior of those parts of the structure accessible to rodents must be constructed of materials resistant to the gnawing of rodents, and all openings must be either permanently closed or protected with tightly fitting doors or with screens of 1cm mesh or less. Generally, the cost of rodent-proofing will amount to less than the loss caused by rodents during a single year. Details and diagrams on the installation of rodent guards for grain cribs are presented in the Peace Corps/VITA Small Farm Grain Storage Manual.

Rodent Poisoning

There is a lack of consensus among experts as to the recommended poison and bait. Rat poisons come in two general forms: single-feeding dosage poisons and multiple-feeding anticoagulants.

Baits are selected for rat preference as well as other factors. Liquid baits are useful where the normal sources of water for rodents are either limited or wholly absent, sometimes with the addition of not more than 10% sugar to the water to improve acceptance. Of the solid baits, moist baits are generally better accepted than dry ones. But moist baits may spoil quickly in hot weather, making it advantageous to use dry baits such as a cereal with sugar and an animal or vegetable fat added. To prevent rats from dragging poisoned bait off to other areas of the store, thereby contaminating clean grain, the bait should be finely pulverized. The Peace Corps/VITA Small Farm Grain Storage Manual gives details on the placement of baiting stations and the selection and dosages of various common rodenticides.

Rodent Trapping

Rodent traps are recommended to avoid the danger of poisoned baits, to avoid the odor of dead rats, and to eliminate bait-shy rats. Traps can be rather costly and require careful placement and management.

The most commonly used traps are the snap trap and the steel trap. Snap traps, sometimes called wood traps or breakback traps, have a flat base. They kill by means of heavy wire, actuated by a spring released by a trigger. Steel traps have a platform trigger and two steel jaws which are snapped together by means of a single, flat spring. Steel traps with approximately 9cm jaws are effective for rats.

Usually the catch in any type of trap will be best the first night, provided the traps are carefully placed. If a rat is caught in each trap the first night, not enough traps have been placed. Because rats quickly become trap shy, trap location should be changed frequently. Traps require servicing at least daily and should have fresh bait. Many persons believe that the trapper must wear gloves when handling traps to avoid leaving human odors, but these odors do not deter rats, which live in close association with humans. It is also unnecessary to wash, boil, or sterilize traps to remove the odor of previously caught rats. Snap traps may be used unbaited if the bait pan is enlarged to provide a platform on which rats may step to release the trigger. It can be enlarged by fastening a 3cm piece of fly screen or cardboard securely to the trap trigger or bait retainer. The trigger must be placed directly in rat runs since there is no bait to lure rats. Boards, boxes, or other obstructions should be placed beside or immediately behind such traps to guide rats into them.

Rodent Fumigation

Fumigation is an excellent means of quickly eliminating rodents in a sealed building, the hold of a ship, a boxcar, grain elevator or sealed bin. However, the use of fumigants is extremely dangerous and even the least hazardous ones should be used only by trained workers. The fumigants most commonly used are hydrogen cyanide, methyl bromide, and phosphine.

Gassing of burrows is used as a supplementary measure for killing rodents. It should not be attempted by untrained operators. Calcium cyanide dust can be blown into a burrow system. It is not, however, effective in extremely dry ground because some moisture is needed to convert the dust to gas. The nearby ground should be observed closely for escaping dust from other holes in the burrow system. These holes should be quickly closed to prevent the escape of either gas or rodents. Burrows may be reopened by rats shortly after they have been gassed. This represents either a failure of the gassing operation or a new rodent infestation and indicates a need for re-treatment.

Q. Recognition of Storage Problems in the Field

Major Subject Areas

- Sources of information and informants to reveal storage problems
- Use of survey and interview for information gathering
- Responses to storage problems

Training Objectives

- Volunteer will know the possible sources of local and regional information and informants for grain storage problems
- Volunteer will be able to conduct informal storage surveys with individual farmers and analyze observations and responses for likely grain loss points and potential prevention measures
- Volunteer will be familiar with the control methods traditionally used by local farmers to reduce problems due to heating, mold, insects, rodents, theft, etc.

Suggested Resources

- Reports from local or relevant regional research and extension projects for storage loss assessment and storage method design and field trials
- FAO Handling and Storage of Food Grains in Tropical and Subtropical Areas, Section 7, Appendix A
- Post Harvest Loss Assessment Methods, Chapter III (AACC publication available from 5340 Pilot Knob Road, St. Paul, Minnesota 55121, U.S.A.

Suggested Training Exercises

- Conduct survey interview with other trainees in local language, then with selected farmers
- Take specific examples of problems cited by farmers and list all possible solutions with critical assessment as to probable viability, practicality, cost, and likelihood of farmer acceptance

Too often traditional or peasant farmers have been assumed to be basically ignorant, at the mercy of an often unfriendly environment, and generally in need of modern, mechanized technology. Fortunately, development specialists are coming to appreciate both the great wealth of knowledge and intelligence of traditional farmers and the idea that traditional farming and storage methods may be logical, practical, scientific, and efficient in terms of available resources and environmental conditions.

Given the initial recognition that farmers are probably making relatively effective use of the resources at their disposal, the development worker or Volunteer who wishes to help improve local farm level storage methods must be a careful observer and design or recommend changes with deliberate attention to their practicality, feasibility, and general appropriateness. Simple, inexpensive alterations or modifications are likely to be more easily accepted and adapted than more involved, complex, or expensive ones. Finally, any changes must obviously respect basic storage principles.

There are four principal sources of identification of storage problems upon which the innovative Volunteer may expand:

1. The storage method survey presented in Section D of this Handbook can be used as a guide to identify local postharvest conditions, storage and drying methods, and potential problem areas which the Volunteer might address. Remember that many questions and answers already exist in the area you are improving. Seek out local thinking comparing the ideas of innovative farmers and extension agents.

2. The results of local research for the design of improved harvesting, drying, storage, or processing methods can be an indication of locally recognized postharvest problems.

3. Past or ongoing extension efforts may have identified improvements which can be expanded upon.

4. The non-availability of storage resources can identify storage problems as well as Volunteer projects. Access to insecticides, cement, wire screening, credit, favorable markets, etc., necessarily determine the range of a farmer's choices regarding postharvest methods.

Use of Survey

The use of a storage survey such as is presented in Section D will help to reveal specific storage problems in addition to other important social, cultural, and behavioral factors such as:

- Farmers' recognition of storage problems
- The resources farmers have at their disposal
- The degree of farmer sophistication in understanding storage problems and storage principles
- The level of farmer concern for specific storage problems
- The degree of farmer awareness of storage quality.

The observations and questions recommended in the survey are general and applicable to a wide range of postharvest conditions. As the Volunteer gains experience and understanding of local storage methods and farmer attitudes, more specific questions and questioning approaches will be identified. The following guidelines are recommended for use of the survey:

1. Be straightforward in stating that the purpose of the interview or visit is to identify storage problems encountered by farmers in an effort to develop a project to help alleviate those problems.

2. Farmers may be reticent to discuss certain details concerning their stored grain. It may be best to avoid any specific questions as to the quantity of the total harvest or sale prices if farmers are concerned about the effect it might have on their taxes, jealousy from other farmers, theft, etc. The Volunteer should attempt to detect such reticence on the farmer's part and will need to tailor the questions and approach of the survey to assure that the informants feel free in sharing accurate information.

3. The survey will probably be most useful if conducted in an informal interview or discussion rather than as a set of ordered questions read from a form. The Volunteer may find it helpful to take brief notes, but should probably avoid recording responses on a form.

4. Get a varied sampling of all types of farmers.

5. Farmers may want advice immediately after sharing their storage problems with the Volunteer. This is understandable,

Q. RECOGNITION OF STORAGE PROBLEMS IN THE FIELD contd.

and it is probably best in terms of the results of the survey if farmers feel they are getting something useful in return or as a result of the time they spend in responding to the Volunteer's questions. If there are reasonably certain improvements which can be recommended, do not hesitate to make suggestions. If that is not the case, promise a follow-up visit. Then do just that, making another visit some weeks later. Even if no specific recommendations can be made at the time, farmers are likely to be more impressed and cooperative with a Volunteer who cares enough to honor a promise to visit again.

6. If you do not know the correct answer to questions farmers may ask, do not be afraid to say so. Promise to look into the matter and then follow up with another visit, even if your response still does not answer the question.

Response to Storage Problems

As the Volunteer interviews and observes a number of farmers, certain storage problems may begin to appear with regularity. They will often be interrelated and not that easily resolved. The most important information in designing a solution to a storage problems comes from the farmer's responses. What have they tried? What works? What doesn't work? Why?

The following is cited as an example of a "worst case" of interrelated conditions which a Volunteer might find:

- Farmers have serious problems with insect and mold losses.
- Grain drying would eliminate mold problems and reduce insect attack, but firewood and fossil fuels for dryer heating are prohibitively expensive.
- Sunning of grain is difficult because of the labor required to move grain under shelter during the unpredictable rains at harvest time.
- Grain could be left to dry longer in the fields before harvest except that birds cause heavy losses and require harvesting at the earliest possible date.
- Insecticides are not in ready supply and those that have been tried leave an unacceptable taste on the grain or become ineffective after three months, requiring emptying the storage bins for re-treatment at a time when there are high labor demands for plowing and preparing the fields.

Q. RECOGNITION OF STORAGE PROBLEMS IN THE FIELD contd.

At first glance this set of interrelated problems does not have any immediately promising solution, and indeed there will be situations in which the Volunteer may be obliged to conclude that the farmers are doing their best under the circumstances. But before that conclusion can be realistically made, all viable options should be examined. The following is a list of common storage problems and possible, though not exhaustive, potential solutions. Neither the problems nor the possible solutions are listed in any order of priority or frequency of occurrence. Remember that some problems are unsolvable because of overriding social, economic or technical reasons.

Storage Problem	Potential Solution
Pre-harvest losses due to birds, monkeys, cattle, pigs, theft, etc.	- harvest at earliest possible date, attending to consequent drying problems - use people (children) to stay in the fields to chase away pests - establish cooperative agreement among farmers to fence, tie, or herd cattle, pigs, goats, etc.
Pre-harvest and field drying losses due to rodents	- (remember that rodent clubbing, poisoning, or trapping in the field is impractical except in the cases of huge population invasions) - harvest and bring grain in from field at earliest possible date - build field-drying platforms with rat guards
Pre-harvest and transport losses due to shattering (notably certain bean and rice varieties become very fragile and fall from the stalk or pod when dry, blown by wind, or jostled during harvest and transport)	- plant other less shatter-prone varieties - harvest as soon as possible - seal gaps, joints, or holes in transport baskets, carts, sacks, etc., to reduce spillage losses in transport
Wind blows down stalks, and rats and rot cause losses	- harvest as early as possible - plant varieties with shorter stalks, or more solid root structure

Q. RECOGNITION OF STORAGE PROBLEMS IN THE FIELD contd.

Storage Problem	Potential Solution
Labor required to harvest or transport from field necessitates leaving grain in field for a long period, exposing grain to pest animals and insect pests	- organize farmers for cooperative harvesting and transport - mechanize harvest and/or transport - use carts pulled by humans, animals or small engines to transport in bulk (may require cooperative ownership or credit purchase) - build temporary or long-term storage structures in the field
Cost of firewood or fossil fuels too expensive for use in grain drying	- use natural or improved solar drying - improve efficiency of dryer fuel consumption with blowers, reduced air flow obstructions, increase height of flue, etc. - burn husks or cobs as alternative fuel - use open storage method permitting increased moisture content for safe storage
Cost of dryer construction and/or operation too expensive for individual farmer	- use less expensive local materials for dryer construction - cooperative dryer ownership - work with government on price incentives for lower moisture content in grain marketing
Sun-drying difficult due to labor requirements for turning grain or moving under shelter during rains	- dry in thinner layers, reducing need for turning - dry on black or dark surfaces - use rakes (simple local manufacture) to turn grain - use covers to shelter drying grain at night and during rains
Contamination during sun-drying by wandering animals, dust, pebbles, etc.	- carefully sweep drying surface before use - pen animals during drying - hard pack dirt drying floor - build slightly inclined concrete drying patios (incline for rain evacuation) - sift, winnow, or screen grain after drying

Q. RECOGNITION OF STORAGE PROBLEMS IN THE FIELD contd.

Storage Problem	Potential Solution
Thatch, wood, or special skills becoming too expensive for dryer, storage construction	- cooperative construction/ ownership - redesign or treat structure to reduce repair or reconstruction frequency - replace expensive renewable materials (ex. metal roof, brick leg supports, mortar lining of mud bins, etc.)
Bulk grain storage desirable, but bulk shelling too labor demanding/expensive	- hand-held or hand-operated shellers - cooperative mechanized shelling - gradual shelling and bulk storage
Shelling causes grain cracking and breakage with consequent insect and mold attack and price reduction	- redesign shelling mechanism for reduced grain damage - properly adjust shelling equipment - experiment with other varieties less prone to breakage - shell at higher or lower moisture
Rodent losses in storage	- install rodent-proofing, e.g., rat guards, impermeable wall construction with mortar layer, fired bricks, wire screening, broken glass or stone layer in wall or floor, metal guards around filling or emptying spouts - clear debris and grass from around bin - clean up general village situation - rodent-proof sources of water - rodent traps or poisons (remember limitations of both)
Insect losses in storage	- dry grain more thoroughly - select only non-infested ears for storage - clean and disinfect bin and equipment before storage - seal against insect entry - use insecticides

Q. RECOGNITION OF STORAGE PROBLEMS IN THE FIELD contd.

Storage Problem	Potential Solution
	- treat with insecticides earlier or more frequently - use new insecticide if there is resistance to present product - regular sun-drying to destroy or drive out infestations - store above cooking fires
New varieties more susceptible to insect attack	- sell new variety harvest as early as possible - try other varieties - further breeding improvements - see insect control solutions
Termites or rotting destroy wooden support frame of bin requiring expense of frequent repair, replacement	- treat wood with creosote, oil, insecticide, encase in concrete footings - set supports on stone foundations - use concrete or brick support posts
Market prices too low at harvest	- organize storage cooperatives for later sale - organize cooperative transport to better markets
Grinding or processing removes large percentage of grain food value	- properly adjust grinders, polishers, etc. - encourage processes which use whole grain products - develop and encourage new food preparations which incorporate previously unused processing bi-products
Molding and rot losses on bin floor	- control bin floor moisture permeation from soil by elevation, coal tar or plastic liners, etc.

R. Design and Field Testing of Improved Storage Technologies

Major Subject Areas

- Concept of Appropriate Technology
- Guidelines for design of appropriate improved storage technologies
- Guidelines for field research trials

Training Objectives

- Volunteer will be able to make recommendations for basic design improvements of local postharvest methods and structures
- Volunteer will be able to set up and monitor field research trials
- Volunteer will be able to select farmers respected in the village who will be cooperative for field research trials

Suggested Resources

- Peace Corps Information Collection and Exchange References on Appropriate Technology
- Peace Corps/VITA Small Farm Grain Storage Manual, Sections 4, 5, 6, 7; Appendices D, E
- L.I.F.E./AACC Post Harvest Grain Loss Assessment Manual, available on request from L.I.F.E., 1126 - 16th Street, N. W., Washington, D. C. 20036
- Small is Beautiful, Economics as If People Mattered, E. Schumacher, available through the Office of Programming and Training Coordination, Peace Corps, 806 Connecticut Avenue, N. W., Washington, D. C. 20525
- Reports of or visits to local or regional storage design and research trials

Suggested Training Exercises

- Plan field research trials with three different improvements and one traditional control with three duplications of each example. Plan all materials necessary, their delivery, tools required, agreements necessary with farmers, and time and type of observations to be made.

R. DESIGN AND FIELD TESTING OF IMPROVED STORAGE TECHNOLOGIES contd.

Successful change of local storage methods will depend largely on the degree to which the program or effort relies and builds on local skills and knowledge, utilizes local resources, and responds to local needs and goals. As one of the countless examples of locally adapted technology, American prairie farmers used sod to build their homes, even though masonry bricks would have been more durable. But bricks were either not easily available or more expensive, so the sod houses were cheaper and easier to build and maintain. Closer to our subject, although subsistence farmers might get better results from chemical insecticides, mixing sand with stored grain may be preferable as it is simpler and less expensive.

This general approach to technological innovation has recently been given a popularly accepted name by the late Ernest Schumacher of Britain. It is called Appropriate Technology (A.T.). A.T. is defined in many, and sometimes conflicting ways, though for the purposes of this Handbook, A.T. refers to technologies which are derived from the needs, goals, knowledge, and resources of the client population (in this case, the small subsistence farmer). Because labor is often more plentiful and cheaper than mechanization, labor-intensive solutions are common to A.T. Schumacher's book, Small is Beautiful, Economics as If People Mattered, is a useful information resource for this section of the Handbook.

Peace Corps Volunteers working in poor or isolated rural areas should quickly recognize the logic of client-oriented technology and employ the basic concepts of A.T. in their work, even without a formal understanding of it. Large storage development projects in the past too often have not used the A.T. approach. Inappropriateness explains the numerous examples of massive, imported, modern storage bins which have been abandoned or never used. The question of large centralized storage installations as opposed to on-farm storage should be examined from the A.T. viewpoint in determining whether expertise and cash resources presently exist to use and maintain, large, modern installations. Railroad and transport infrastructures must exist to bring large quantities of grain to central storage locations. In fact, farmers may be able to store and handle grain themselves at a lower cost, higher efficiency, and with lower losses.

Under any climatic conditions, the major dangers to safe storage can be controlled by employing a variety of often highly mechanized and sophisticated, though not necessarily appropriate, technologies. However, farmers' non-acceptance of "modern" storage bins or grain dryers results in no improvement in grain storage conditions. Among the most common reasons for farmer non-acceptance of new storage technologies are that the new methods simply do not function properly in the local climate, are too expensive, too difficult to repair and use, or are in conflict with local cultural practices.

Education and extension can change cultural values and practices and teach farmers how to adopt and use new storage methods although this may be a long and slow process. However, before education and extension can begin effectively, the basic design and feasibility of the new method must be carefully examined. The important point here is the development project planner and extension worker have the responsibility to recognize and effectively deal with these technology design and transfer problems.

Before a new storage method can be advocated for farmer adoption, its technical, economic and cultural viability must be verified along with the ability of the extension/educational system to successfully introduce it. To increase the likelihood of successful adoption, careful, systematic, applied research is required to explore all possible approaches. But research in the laboratory or on the research farm cannot replace actual on-farm trials. Such field trials, however, must be repeated if the multitude of social, technical, economic, and cultural factors are to be clearly understood and dealt with. They are not necessarily complex nor do they necessarily require advanced technical expertise. In fact, available resources may dictate that they make do with meager technical support and resources. The following guidelines are recommended for improved storage method design and for the conduct of field research trials.

Guidelines for the Design of Improved Storage Technologies

Technical Viability

Above all other considerations, improved storage technologies must function properly under local conditions. Guarantees from foreign manufacturers may have no relationship to the reality of a farmer's environmental conditions of intense heat, torrential rains, dust storms, etc. If field tests are properly conducted, technical viability should be readily apparent. For example, airtight storage is not an approximate technology. Unless the container is and stays airtight, insect control just will not happen. Does grain actually dry or stay dry? Does the insecticide lose its effectiveness over time? Does the rat guard actually stop rats? Is the plastic liner easily pierced by sharp objects or rodents? Does moisture seep up through the "moisture-proof" barrier? These situations may sound unlikely; yet they are not.

Cost

The cost of improvements must be compared to:

1. The realistic grain value saved as a direct result of the improved technology, and

2. The cost of the old technology and the realistic value of the losses inherent in that technology.

A very basic calculation of the cost of any technology includes the initial materials cost, projected repair expenses, projected total depreciation, and labor costs by the farmer or hired help. Labor costs may be difficult to evaluate if the farmer does the work him/herself. In this case, the most useful evaluation of the required labor may come directly from the farmer who has had actual experience with both technologies in question. He/she will likely consider not only the time and effort required, but the competing labor demands, the storage quality outcome, and the labor requirements for repair and use.

Some technologies may be viable in terms of the value of grain saved, but inappropriate for the average farmer. At times, projects may opt to deal with above-average income farmers for the simple reason that little significant improvement can be brought to the level of the average farmer. Such projects should be very carefully reviewed as they may have long-range ramifications on the economics of a whole area, possibly increasing land ownership by the wealthy, increasing the number of landless poor, and encouraging their immigration to urban areas.

Practicality

The access and dependability of material supplies need careful examination. For example, what happens during fuel shortage if dryer fuel is needed to avoid a mold problem? The increased dependence on imported materials and resultant foreign cash flow may not be advantageous to a developing nation. However, imports may have their own unique problems in regularity of supply.

New skills required in the construction, use, and maintenance of a technology may have a major effect on its practicality.

R. DESIGN AND FIELD TESTING OF IMPROVED STORAGE TECHNOLOGIES contd.

In the time you will be available, can farmers or skilled tradespersons learn the necessary skills, enabling independent, unsupervised operation? If not, increasing acceptance of the technology will create greater and greater demands for extension support. Can farmers or skilled tradespersons read and understand printed instructions for construction, operation, and maintenance?

Cultural Considerations

Established labor patterns--If men tend to harvest while women and children transport, dry, shell, grind, and store grain, labor patterns (and potential changes in ownership) need to be known and accounted for in the design of new technologies. If women store, the bins need to be designed so that women can use them, including special design factors for height and weight considerations. Labor requirements during construction and use need to be accounted for. Specifically, how much and whose actual labor is required? What else must be accomplished at the same time? What will take priority?

Cultural and religious beliefs--These can be very complex and difficult to learn and appreciate by an outsider who may have very different belief systems. The following general areas need attention:

- Status--Does grain, its visibility, quantity, quality, or manner of storage add or detract from a farmer's status?
- Religion--Does grain or its products play a role in the farmer's religion? Is it sacred, or is its possession considered to be a temporary condition bestowed by a divine force? Are losses to rodents, birds, etc., considered as the farmer's contribution to the life around him?
- Family--Is grain needed as gifts to needy family or friends, for weddings, funerals, and the like? Does a visible grain bin invite less fortunates to request aid? Will this influence how much the farmer will want to store or the desired visibility of the bin?
- Theft--Is it a problem? Will new storage methods help to prevent it? Will they encourage it?
- Food taste and texture--Do improved technologies, which cause changes in grain and grain product texture and

taste, cause it to be unacceptable? Some insecticides may cause problems, as may new drying processes. Field testing will reveal such dietary acceptance problems.

Guidelines for Conducting Field Research Trials

Insure minimal farmer risk--Farmers should be asked to test only new methods which are reasonably certain of success. Abysmal failures set very bad precedents and make poor advertising for a new project. If new methods under consideration have a very uncertain chance of success, the trials should be conducted in the Volunteer's backyard or on a research farm, where failure will not risk heavy losses by the farmer or give bad publicity to the project. However, this sheltered testing environment can never replace actual farm trials. Farmers should be insured against unforeseen losses due to possible failure of the new technology either by replacing the lost grain or paying its cash value. Any new costs of the trial technology should be paid partly or in full by the farmer. Caution needs to be exercised, to assure that farmers in the area do not come to think that the new silo, dryer, etc., is always going to be handed out as a gift.

Repeat--A single design trial is seldom enough even though trial extension efforts may begin while design trials continue. Climatic conditions, as well as insect and rodent infestations, may vary from year to year. One farmer may behave very differently from others, making it necessary to run trials with a variety of famers: old and young, wealthy and poor, those located near cities, etc.

Run trials in the real farm milieu--Research farms and Volunteers' yards are not typical farm conditions. The sooner farmers learn and perform certain tasks involved with the technology in the context of the trials, the more likely the results are going to reflect real problems or shortfalls.

Compare with traditional methods--Ideally this should be done by observing both technologies in operation by the same farmer. Compare weight losses from the beginning of the storage period to the end. Volume losses are much more difficult to assign meaningful values to.

Assign cash values--Assign a realistic value to the cost of each technology and its components, to the grain losses or savings due to each.

Be aware of cultural variables--Farmers who are chosen to participate in research trials must be cooperative and follow instructions. Furthermore, they should be representative of the average farmer population. This may be difficult to achieve if only the most innovative farmers are willing to cooperate. Ideally, trial farmers should be well-respected in their village or area so that results will be trusted by neighboring farmers and so that their example and recommendations will be respected and followed. Trial farmers may be so eager to cooperate that they cover up problems just to please the Volunteer or trial supervisor.

5. Extension of Improved Storage Technologies

Major Subject Areas

- Common extension service shortfalls
- Farm visitation
- Demonstration
- Indirect extension methods
- Training yourself out of a job

Training Objectives

- Volunteer will be familiar with local **extension hierarchy** and location of local field extension **agents**
- Volunteer will be familiar with all **past extension efforts** in local small farm grain storage

Suggested Resources

- Peace Corps/VITA Small Farm Grain Storage Manual
- Peace Corps, The Photo Novel: A Tool for Development
- Agricultural Extension: The Training and Visit System, Daniel Benor and James Q. Harrison, World Bank, 1977, available on request from the World Bank, 1818 H Street, N. W., Washington, D. C. 20433 or any regional office.
- Educational Tours, A Guide for Extension and Village Workers, Extension Service, USDA/USAID 1974, available through Information Collection and Exchange (I.C.E.), Peace Corps, Washington, D. C. 20525.
- Farm and Home Visits, A Guide for Extension and Village Workers, Extension Service, USDA/USAID 1974, available through Information Collection and Exchange (I.C.E.), Peace Corps, Washington, D. C. 20525.
- Using Visuals in Agricultural Extension Programs, United States International Cooperation Admiministration, available through ICE, Peace Corps, Washington, D. C.

Training Exercises

- Practice a farm visitation with emphasis on gaining farmer's trust and interest
- Make a plan for and map out farm visitation schedule
- Design posters to advertise the various potentials of improved storage methods
- Plan a 2-4 minute radio spot to advertise some form of improved storage
- Investigate possibility of presenting a booth or demonstration at the next area agricultural fair
- Visit the agricultural extension training center and build a storage model there for use in training extension agents

* * *

Agricultural extension is the term used to refer to the process of education and encouragement of farmers to adopt new or improved farming methods. Though it is a vital link in agricultural development programs, the extension service in developing countries is often both inadequate and ineffective. The most common reasons for this are:

- Insufficient number and mobility of extension agents to reach numbers of farmers
- Inadequate training of extension agents and insufficient contact with updating of technologies and information
- Low status of extension workers, low pay, and lack of respect by farmers
- Duplication of services with several branches or offices having overlapping authority and duties
- Use of extension agents for non-extension activities such as census taking, farm data gathering, materials supply, credit management, etc.

For an extension effort to be successful in motivating farmers to improve their farming practices, there must be some clear incentive for the farmer. The most common and successful incentive is increased profits, whether as a result of increased production, reduced losses, or reduced labor requirements. If improved storage methods are to be widely adopted, farmers need to be convinced that there is a clear practical advantage to the new methods. Extension efforts need to be planned with that goal in mind. Answers to the following questions can help shape the planning of an extension strategy:

- What exactly are the changes the farmer will be encouraged to make?
- What are the advantages to the farmer?
- What new cash investments will be necessary? What is the expected rate of return on the new investment?
- What credit is available for the project? Is it adequate? Who can qualify?
- What new or additional resources will be needed, e.g., mud bricks, cement, rat guards, insecticides, etc.?
- How will these additional supplies or resources be delivered to the farmer?
- Which member of the family will be primarily responsible for making the decision to change from present methods?
- Who will be responsible for the labor required to construct, use, and maintain the new method?
- What new skills or knowledge are required by the new method?
- What kind of training will be needed by the extension agents? What training do they presently receive? What continuing information and supervision will be needed by extension agents and by farmers?

Appealing to a Wide Range of Farmers

Rather than promoting one standard procedure which may be too demanding for small or poor farmers and inadequate for larger farmers, a variety of possible recommendations suitable to the varying resources and abilities of area farmers should be presented. Ideally, farmers would be encouraged to begin with small changes and, as those prove successful, adopt more expensive or complex changes.

Farm Visitation

Farm visitations should be scheduled on a frequent and regular basis, such as twice monthly on a specific day of the week. This allows farmers to schedule their work around extension visits. The regularity also helps to build familiarity and trust. Too often farmers are visited only 3-4 times a year and have little opportunity to establish a friendly relationship with extension agents. As a result, they learn very little from the visits.

Rather than attempting to reach all of the farmers in any given area, a limited number should be chosen either on a group or individual basis. If the farmers in the extension program are carefully chosen, they will serve as communications links with the rest of the farmers in the area. Farmers chosen to participate in the extension program should be representative of the total farm population, varying in age, family size, farm size, wealth, education, etc. If only the most progressive farmers are included in the extension program, average farmers may not identify with them or follow their example. The selection of participant farmers could be discussed with village leaders or elders. Farmers who are chosen should agree to explain recommendations to neighboring farmers, allow them to visit their farms, and be willing to answer their questions.

Demonstration

The single most effective method of convincing farmers to adopt new storage methods is by demonstration. It is, therefore, often the most effective extension technique, particularly when a demonstration is set up to insure that a large number of farmers can see it, hear it explained, and discuss it among themselves. Demonstration sites should be carefully chosen to allow for adequate supervision, easy access, and high visibility. School gardens, public lands near market places or rural clinics, etc., make highly visible locations. However, when the demonstration involves the construction of a permanent structure, extra care needs to be exercised in planning to allow for long-range supervision and use. Abandoned silos or dryers do not make good publicity when funds or interest to keep them in proper use and maintenance run out.

Learning from Farmers through Extension

The reactions of farmers to extension demonstrations and their success or failure can be very useful in further improving the extension strategy and the storage method itself. Farmers should be encouraged to react to the ideas and methods presented and every possible effort should be made to accommodate their suggestions and criticisms.

Indirect Extension Methods

There are a number of indirect ways of communicating with farmers to convince them that new techniques are worth a try The most common of such methods involves the use of agricultural fairs and demonstrations, radio programs and announcements, posters, newsletters, and advertisements.

The Peace Corps publication, The Photo Novel: A Tool for Development gives details on the use of photographs which tell how to demonstrate a new idea or method. It has proven to be a very successful extension method in some countries in Latin America. Where resources are limited, the idea might be used in single-page flyers or posters. Also, the Peace Corps/VITA Small Farm Grain Storage Manual has a variety of illustrations and subject-specific farmer training guidelines which may prove useful with some local adaptation.

Using Radio as an Extension Tool

Radio spots, informative talks and farmer interviews can be very useful in reaching large numbers of farmers and extended farm families in urban areas who may convey the new ideas to relatives in rural areas. Radio spots and informative talks should usually not be longer than five minutes and should best be scheduled for broadcast during farmers' non-working hours. Radio spots of longer than five minutes are very difficult to keep interesting enough to maintain the interest of the listeners. Farmer interviews should not be longer than ten minutes and can be very useful in publicizing the results of demonstration trials. The following are general guidelines for planning and broadcasting radio extension programs:

- Keep the program lively and interesting
- Summarize the points to be presented at the beginning and several times during the program

- Identify the subject to be discussed, tell why it is a problem, what can be done about it, the results which can be expected
- Rehearse the program until the materials are really familiar
- Use the name and location of farmers who have successfully used the new method
- Give and repeat contact addresses for further information or follow-up
- Advertise the program well ahead of time through radio, posters, newspapers and direct extension contact

Training Yourself Out of A Job

Peace Corps philosophy encourages Volunteers to consciously train themselves out of a job. If a Volunteer ends his/her service before training a local counterpart in the work done by the Volunteer, chances are poor that this role will ever be filled by a local person. Further training and supervisory inputs would again be necessary. The goal of training local counterparts in all of a Volunteer's work roles is far from easily attained. Ask a few experienced Volunteers how successful they were. Development and change is usually a very gradual process even though general goals may be very clear and widely accepted, such as reducing grain losses to increase the food supply. Real progress in development hinges on the communication and teaching of new skills and knowledge so that local people are able to take more control over their own lives, planning and innovating as their needs and priorities direct.

APPENDIX A

APPENDIX A

PEACE CORPS COSTA RICA GRAIN STORAGE PROJECT REPORT

Submitted to Juan Coward, Costa Rica Associate Peace Corps
Director/Agriculture

Prepared by The League for International Food Education

L.I.F.E. Team Members:
Theodore Granovsky, Texas A&M University
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Robert Morris, Consultant, Washington, D. C.

BACKGROUND

The Costa Rican Consejo National de Produccion (CNP) placed a request through Juan Coward of Peace Corps Costa Rica for the recruitment, training and placement of eight volunteers to work in a new small farm storage project. The CNP is a Costa Rican government organization responsible for the purchase, storage, and resale of basic grains produced in Costa Rica (maize, rice, millet and beans). The general CNP goal for the requested PCV's is to assist small farmers in improving their grain drying and storage practices such that better quality grain will be sold to the CNP and the farmers in turn will receive higher prices for their grain.

The League for International Food Education (L.I.F.E.) is a Washington, D. C. based, non-profit organization funded primarily through the Office of Nutrition, Development Support Bureau, USAID. L.I.F.E. is a consortium of nine U.S. scientific and professional organizations united together to provide information and assistance in solving technical problems in nutrition, food technology and child feeding programs in developing countries. The attached brochure* gives more details of L.I.F.E. and its functions. One of L.I.F.E.'s projects, funded through USAID, is to develop and test an internationally acceptable methodology for assessing post-harvest grain losses. As such, the L.I.F.E. Grain Loss Project has been in active cooperation and communication with all major development organizations working in this area.

Mr. Coward, who visited Washington, D. C. in January, 1978, requested a briefing from L.I.F.E. on available technical assistance resources for the programming, training and ongoing technical supervision of the CNP-requested PCV's. During the three days of his contacts with L.I.F.E. and through subsequent communications, arrangements were made to secure a mission to Costa Rica by a team of L.I.F.E. Grain Loss Project consultants.

The L.I.F.E. team spent April 22-29, 1978, in-country to accomplish the following three objectives:

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*Not attached; may be obtained from L.I.F.E., 1126 - 16th Street, N.W., Washington, D.C. 20036

APPENDIX A contd.

1. Set forth proposed activities and job descriptions for the requested PCV's.

2. Outline Volunteer recruitment criteria and training needs.

3. Outline the various technical assistance needs of the project and relevant resource organizations which could be called upon to respond to these technical assistance needs.

The L.I.F.E. team travelled to two regions in Costa Rica: Pacifico Sur, on the southern coast near the Panama border; and Pacifico Norte, somewhat inland in the area of the city of San Carlos. These are two of the five possible areas where volunteer placement is under consideration.

Both areas have high rainfall and two major cropping seasons. In Pacifico Sur most farmers contacted were recent "colonists" who had been given government-sponsored credit for the purchase and cultivation of abandoned banana plantation land. These farmers are challenged by cultivation and storage in a climate and area often unfamiliar to them. In both areas, the crops under consideration were principally maize and beans.

Drying and storage methods consist of a variety of traditional and more modern techniques. Drying is done largely in the field before harvest and particularly in the case of beans, solar drying is done on canvas tarpolins before and at irregular intervals during the storage period. Storage of maize takes place principally in covered wooden bins in or near the home, or in open weave bags under the shelter of the home roof. Beans are stored shelled, often with pulverized plant and pod material mixed in for insect control, and placed in open weave bags. Less frequently beans are stored in metal 55-gallon drums which can be sealed.

In both areas visited, post-harvest loss prevention can be broken down to the following general, though not all inclusive, categories:

1. Field standing losses due to birds, rodents and other animals.

2. Inadequate pre-storage drying with resultant losses due to fungi and insects.

3. Insect, rodent, and fungi losses during storage.

APPENDIX A contd.

PROJECT DESCRIPTION

The overall purpose of this project is to involve eight PCV's in identifying:

1. Local, small farmer grain storage problems (principally maize, with lesser emphasis on beans and rice).
2. Appropriate, practical storage methods which reduce post-harvest losses.
3. Extension of these improved storage methods to area small farmers.
4. Secondary volunteer activities will be in the extension of improved basic grain cultivation procedures.

PROJECT JUSTIFICATION

The project plan set forth in this report and the consequent technical approach is based on the following factors:

1. There exists a variety of small farmer post-harvest drying and storage practices in areas visited. Some of these methods appear to be more successful in loss prevention than others.
2. Particularly in areas where newly-settled "colonists" comprise much of the small farmer population, locally evolved, relatively successful post-harvest practices are not well known to the "colonists." Observation and rudimentary analysis of the varied methods utilized in any area will point to which, if any, of the local methods prevent losses most satisfactorily. This measure of success is not solely technical. It must include practical cultural and economic considerations.
3. Various appropriate post-harvest technologies exist which are not currently known or used in the areas visited. Such technologies should be carefully considered and systematically tested for practical and technical viability in the areas served by volunteers. Those "improved" and local technologies which are most successful in loss prevention should be cautiously introduced to small farmers through a carefully planned and monitored extension effort.
4. Ongoing observation of technology test-trials and extension efforts will serve to continually refine and improve both the post-harvest technologies and the extension mechanism.

APPENDIX A contd.

PROJECT OBJECTIVES

Months 1 - 6:

Survey 75-100 local small farmers selected at random from a plotting map using the CIGRAS*model for random selection and survey questionnaire in order to identify progressive farmers, common drying and storage methods. Collect insects encountered from 50 small farm storage sites. Insect specimens will be sent to CIGRAS for identification. Volunteers will, as a secondary activity, advise on basic grains cultivation practices with contacted farmers.

Months 6 - 12:

1. Participate in in-service training session for planning and initiation of demonstration and extension presentations on improved drying and storage.
2. Set up drying and storage demonstration sites in the volunteer's region.
3. Take moisture content samples from grain at doubling, at harvest, after drying and at monthly intervals during storage from five progressive farmers and five non-progressive farmers. Samples will be sent to CIGRAS for analysis of aflatoxin presence. Samples will be replaced with grain supplied by the CNP.
4. Make a collection of grains damanged by birds, rodents, insects and fungi.

Months 12 - 18:

1. Continue 3 and 5 above taking moisture samples.
2. Further refine and continue demonstrations.
3. Place five metal bins of 800-1000 kg capacity with progressive farmers (bins to be manufactured in San Jose).
4. Supervise improved grain drying and fumigation.
5. Experiment with cheaper and/or more effective drying tarps, experiment with darkened staining or drying patios, etc.

*Grain and Seed Research Centre of the University of Costa Rica.

Month 14: Participate in two-three day seminar to:

1. Review and evaluate activities.
2. Identify most effective appropriate storage technologies.
3. Develop two-year plan for continued storage activities in present locale.
4. Write job description and make two-year plan for PCV's in new areas.
5. Evaluate potential for local manufacture of appropriate storage technology, including metal bins, drying and other relevant equipment.

Months 18 - 24:

1. Develop extension materials with L.I.F.E. coordination for area-wide dissemination.
2. Continue refinement and demonstration of improved storage practices.

RECRUITMENT CRITERIA

Trainees should have some Spanish background (0+/1 minimum) with farm background (4-H, FFA or direct farming experience) and/or agricultural training at high school or post-high school level.

TRAINING

Pre-Service

1. (Five days) Basic grain cultivation practices to include planting, fertilization, cultivation, seed certification and improved and local grain varieties. Visit to CIGRAS with introduction to grain storage principles and practices.
2. (Two days) Basic grain storage principles including interrelationship and control of moisture content, insects, rats, mice, and birds, mold and fungi. Visit to CNP for presentation and discussion of project objectives.

APPENDIX A contd.

3. (One day) Damage identification techniques for rodent, bird, insect and fungi losses.

4. (One-two days) Use of post-harvest survey questionnaire including random sampling and random selection of farmers, random grain sample selection and transport, and principles and use of moisture meters.

5. (Two-three days) Review of common Costa Rican harvest, drying and storage practices, including doubling, above fire storage, wooden bins, drying tarps, drying patios, insecticides available and the common and/or proper use, insect identification with second field visit to CIGRAS laboratory.

6. (One-half day) Principles and philosophy of appropriate technology, including cost, construction, maintenance, utility and cultural factors.

In-Service Training (end of first six months)

1. Review storage principles, i.e., relative humidity, moisture, migration, etc.

2. Review of common drying practices taken from survey.

3. Review of common storage practices as per survey.

4. Plan demonstrations of most successful practices suitable to individual PCV sites as revealed through evaluation of parts 2 and 3.

5. Discussion of application of Appropriate Technology Principles to encourage PCV's to think of design needs for cost, practicality, etc., where new technologies are proposed. Is it practical? Can farmers procure, use, maintain after PCV involvement?

6. Discussion of demonstration methods and techniques and common demonstration problems.

7. Review of function of moisture meter.

8. Review of random sampling techniques.

9. Discuss collection and mounting techniques for pest-damaged corn ears and beans.

10. Explain and discuss sample selection techniques from ten farm sites and sample transportation logistics.

11. Discuss insecticide use and proper dosage and possible extension methods to encourage proper insecticide use.

14-Month Training Session

1. Test for knowledge of proper use of insecticides and dosages (fumigant and contact insecticides).
2. Plan further appropriate technology experiments.
3. Plan logistics of five metal bin placement.
4. Review accomplishments.
5. Develop and discuss a two-year PCV plan.
6. Write job descriptions for next group of PCV's.

SITE SELECTION

Each PCV should be placed within one day's travel to at least one other storage PCV in order to facilitate collaboration and shared learning during the project's early evolution. This strong recommendation is given with acceptance of the desirability of placing individual PCV's far enough from each other to foster an independent volunteer experience.

A PCV site should be carefully investigated in or near at least one of the more isolated Indian tribes. The information and experience derived from these indigenous cultures should be very enlightening in identifying and assessing the various forms of traditionally evolved storage methods. These methods should be carefully studied for potential generalization in other parts of Costa Rica, particularly where newly-arrived "colonists" are unfamiliar with local climate, local storage problems and locally available methods of addressing those problems in drying and storing grain.

TECHNICAL ASSISTANCE

The Peace Corps Costa Rica Grain Storage Project has available to it a wide variety of technical assistance sources. These should be fully utilized on an ongoing basis, but particularly in the early evolution of the project.

APPENDIX A contd.

The various technical assistance sources available locally include, among others, the Consejo National de Produccion (CNP), the Grain and Seed Research Center of the University of Costa Rica (CIGRAS), and the Center for Human Potential (CHP). Other non-local technical assistance resources include L.I.F.E. and the Group for Assistance on Grain Storage (GASGA) which is composed of United Nations Food and Agricultural Organization, English, French, Candian, Belgian, Australian and American member institutions. GASGA assistance through any of its member organizations can be requested through the secretariat at the Tropical Stored Products Institute, Tropical Stored Products Centre, London Road, Slough, Berks SL3 7HL, England.

L.I.F.E. assistance can be requested at 1126 - 16th Street, N.W., Room 404, Washington, D. C. 20036. The L.I.F.E. Grain Loss Project considers this Peace Corps Grain Storage Project to be one of important potential and, as such, encourages any further utilization of its resources in the project's further development and evolution.

Once staging and pre-service training have taken place, one possible alternative to maintain active communication with and utilization of the technical assistance sources could be achieved by appointing or electing one PCV as the Technical Assistance Liaison. The PCV with the most extensive and relevant agricultural experience would likely be the best choice here. However, commitment, interest, social skills and communication logistics should also be considered.

SOURCES

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Since 1961 when the Peace Corps was created, more than 80,000 U.S. citizens have served as Volunteers in developing countries, living and working among the people of the Third World as colleagues and co-workers. Today 6000 PCVs are involved in programs designed to help strengthen local capacity to address such fundamental concerns as food production, water supply, energy development, nutrition and health education and reforestation.

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